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## IMITATION MODELING THE DISCRETE COMMUNICATION CHANNEL IN MATLAB STATEFLOW ON BASIS OF PETROVICH MODEL

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## IMITATION MODELING THE DISCRETE COMMUNICATION CHANNEL IN MATLAB STATEFLOW ON BASIS OF PETROVICH MODEL

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**Abstract:** The article defines the study of a discrete communication channel based on the Petrovich model, amending the faults and its simulation model using MATLAB software. In addition, to reduce the probability of multiple errors in data transmission, coding the discrete channel up to a fault tolerance level, to investigate the distribution of error-free transmission intervals in the discrete channel based on the Petrovich model, to construct the Petrovich model for the discrete channel, The State-flow diagram of Petrovich model is presented for the under research discrete channel. The processes meant by the article save real-time mode of technical engineers in the field of communication services. The research investigation have been carried out on the improvement of the created simulation model which enables the programmers to control the object remotely, to detect errors and shortcomings early, and to take corrective measures.

**Keywords:** network, model, simulation model, discrete channel, transmission, reception, coding, control area, data area.

### Introduction

Currently, the processes in the field of increasing the capacity of discrete communication channels, improving the quality of communication systems are inextricably linked with the development of digital data transmission technologies. In this case, it is necessary to solve the problems of synchronization, effective coding, quality and reliable transmission of information on discrete communication channels [1]. In its turn, requires the use of different models to study the probabilistic characteristics of a discrete channel in modern telecommunications networks (in particular, the accurate distribution of the duration of error-free transmission intervals).

### Research methodology

At the channel level, the data block (frame) is formed at the channel level with the following panel: start flag, address panel, control panel, data store, control amount panel, and end flag. The control amount is the process of fulfilling the amount of the remaining amount resulting from the multiplication of the data frame polynomial into the standard-forming polynomial. A system-level data packet is placed in the frame data panel [1,2,3].

The data frame created at the channel level is transmitted to the physical capacity of the network. The data frame with a length of  $n^k$  at the physical level, is divided into  $k$  bits words with a length of  $n$  bits. Formerly  $m^k$  result is obtained:

$$m^k = \left[ \frac{n^k}{k} \right] \quad (1)$$

Coding will provide the tolerance of the last words to the technical errors. According to the selected coding method the  $r$  bit length inspection discharge is determined. In this case, the length of the word at the physical level:

$$n^F = k + r$$

The unit nominal  $p_0^F$  of communication channel is considered binomial when there is a probability of error. In this case, the probability of occurrence of  $i$  – fold errors in the word is determined by the formula:

$$P^F(i) = C_{n^F}^i \cdot (p_0^F)^i \cdot (1 - p_0^F)^{n^F-i} \quad (2)$$

The coded words in the communication channel come down to the physical level of the receiving parties. This is where word errors are corrected and decoded.  $t_{ex}$  times (weight) error is corrected at  $d_0$ , which is Hamming's minimum code distance:

$$d_0 = 2t_{ex} + 1,$$

If all  $t_{ex}$  multiplied errors in decoding a word are corrected, the probability of receiving the word in error is equal to:

$$P_{op}^F = \sum_{i=t_{ex}+1}^{n^F} P^F(i) \quad (3)$$

The mean (equivalent) value of the probability of an error in a word related to a fault-tolerant bit of code can be determined as follows:

$$p_e^F = \frac{P_{op}^F}{n^F} \quad (4)$$

The information bits of the corrected word are transmitted to the channel level of the receiver.

The data frame is formed from the information bits of words at the channel level. The probability of  $i$  – fold errors in the data frame is determined as follows:

$$P^K(i) = C_{n^K}^i \cdot (p_e^F)^i \cdot (1 - p_e^F)^{n^K-i} \quad (5)$$

The probability of receiving the data frame correctly is as follows:

$$P_{pp}^K = (1 - p_e^F)^{n^K} \quad (6)$$

The probability of undetected errors in the data frame is determined by the following formula:

$$P_{nc}^K \approx \frac{1}{2^r} \cdot \sum_{i=d_0}^{n^K} [C_{n^K}^i \cdot (p_e^F)^i \cdot (1 - p_e^F)^{n^K-i}], \quad (7)$$

Hereby,  $r$  is the number of CRC discharges. In standard protocols,  $r$  is equal to 16 or 32.

The probability of detecting errors in the data frame is determined as follows:

$$P_{oo}^K = 1 - (P_{pp}^K + P_{nc}^K) \quad (8)$$

Here, after checking the reliability of the data frame by comparing the control amount, the probability of error is determined and the supplier is given a negative receipt of  $n^{kb}$  length. Otherwise, the frame will be issued with a positive receipt [2,3 4].

When a supplier receives a frame with a negative receipt, it re-executes the previously delivered data frame, and if a positive receipt is received for the delivered frame, it continues to deliver the next data image. The return channel can be said to be excellent due to the low probability of an error that can be made when receiving a receipt. Such an algorithm is used in many standard protocols and is called the method of data feedback or automatic retrieval (ARQ, Automatic Repeat Quest). The  $i$  – probability of data frame transmission is determined as follows:

$$P^K(i) = (1 - P_{oo}^K) \cdot (P_{oo}^K)^{i-1}. \quad (9)$$

The probability of invalidation of the rest of the data frame after repeated deliveries is determined as follows:

$$P_{oe}^K = \sum_{i=1}^{N_p} [P_{ne}^K \cdot (P_{oo}^K)^{i-1}] = \frac{P_{ne}^K \cdot (1 - (P_{oo}^K)^{N_p-1})}{1 - P_{oo}^K}, \quad (10)$$

$N_p$  – maximum number of repetitions

### Analysis and results

The amounts of re-delivering the channel-level (frame) data block and the probability of retransmitting invalidity have been investigated. Different models are used to test the probabilistic characteristics of a discrete channel. One of the most efficient models of reliable data transmission is the Petrovich model (Figure 1) [4,5,6]. The main features of this model are as follows:

the discrete channel is in 1 to 4 positions, 2 of good and 2 of bad proportion. At the same time, the probability of making a mistake in the "good" case is  $p_{10} = p_{40} = 0$ , the probability of making a mistake in the "bad" case is 1. (As a rule  $p_{20} \approx 0.5$  and  $p_{30} = 0.5$ ).

However, the following results can be obtained as a result of using the Petrovich model:

$$\begin{aligned} p_{11} &\gg p_{12}; & p_{11} + p_{12} &= 1; \\ p_{24} &\gg p_{23}; & p_{24} + p_{23} &= 1; \\ p_{44} &\gg p_{43}; & p_{44} + p_{43} &= 1; \\ p_{32} &\gg p_{31}; & p_{32} + p_{31} &= 1, \end{aligned}$$

In this case,  $p_{ij}$  is the state of the channel when it changes from state  $i$  to state  $j$ .

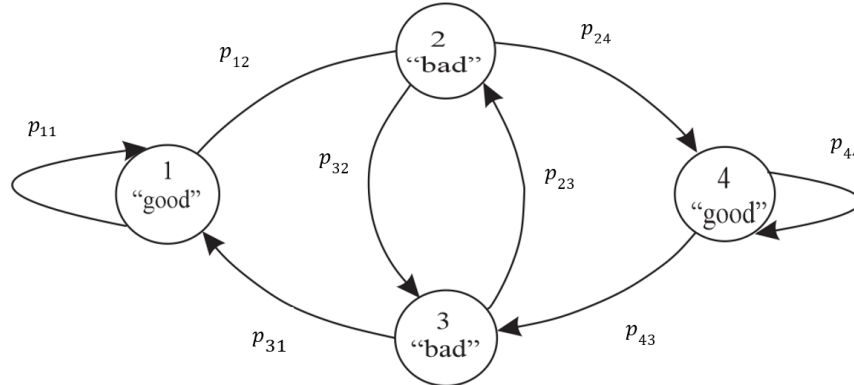


Figure 1. Petrovich model for discrete channel.

According to the model the following result is received:

$$\Rightarrow \begin{cases} p_{11}P_1 - p_{12}P_1 + p_{31}P_3 - p_{11}P_1 = 0 \\ p_{12}P_1 - p_{23}P_2 - p_{24}P_2 + p_{32}P_3 = 0 \\ p_{23}P_2 - p_{32}P_3 - p_{31}P_3 + p_{43}P_4 = 0 \\ p_{44}P_4 + p_{24}P_2 - p_{43}P_4 - p_{44}P_4 = 0 \\ -p_{12}P_1 + p_{31}P_3 = 0 \\ p_{12}P_1 - p_{23}P_2 - p_{24}P_2 + p_{32}P_3 = 0 \\ p_{23}P_2 - p_{32}P_3 - p_{31}P_3 + p_{43}P_4 = 0 \\ p_{24}P_2 - p_{43}P_4 = 0 \end{cases} \quad (11)$$

In this case  $P_i$  is the probability that the channel in position 1 is located.

The sum of all probabilities must be 1:  $P_1 + P_2 + P_3 + P_4 = 1$ , and the following result can be achieved:

$$P_1 = \frac{p_{24}p_{31}p_{43}}{p_{24}p_{31}p_{43} + 2p_{31}p_{43}^2 + p_{12}p_{24}^2}$$

$$P_2 = P_3 = \frac{p_{31}p_{43}^2}{p_{24}p_{31}p_{43} + p_{31}p_{43}^2 + p_{12}p_{24}^2},$$

$$P_4 = \frac{p_{12}p_{24}^2}{p_{24}p_{31}p_{43} + 2p_{31}p_{43}^2 + p_{12}p_{24}^2}.$$

To implement this model in a MATLAB environment, it is recommended to perform the scheme illustrated in Figure 2.

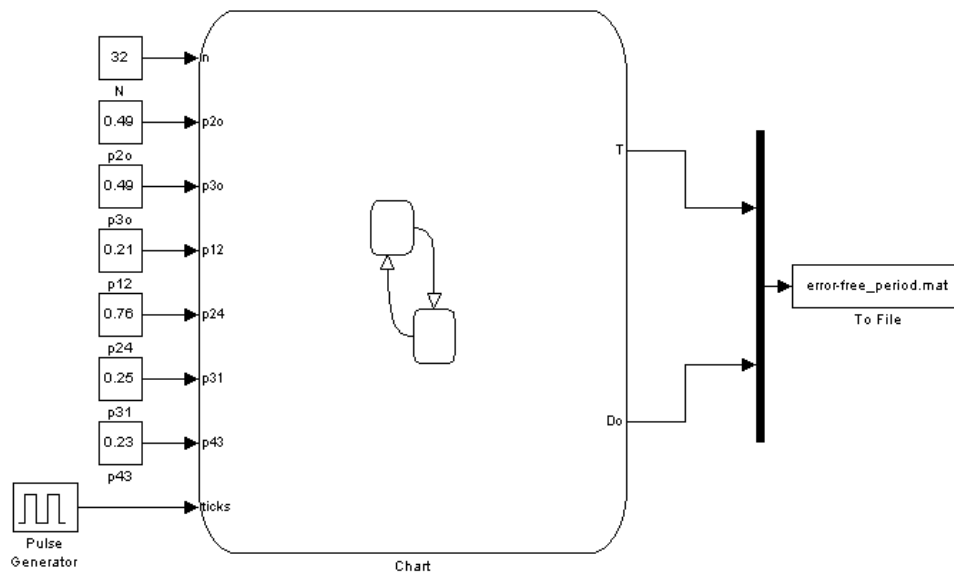


Figure 2. Petrovich model being investigated for a discrete channel:

This model includes the following blocks:

- Constant;
- Pulse Generator;
- Chart;
- To File;
- Display;
- Mux.

The description of the blocks used in the model can be given as follows:

The Petrovich model requires the creation of an SF-diagram in the Char block (see Figure 2) to investigate the distribution of error-free transmission intervals in a discrete channel (Figure 3).

The following variables are used in the current SF-diagram:

Introduction

- a)  $n$  – the number of coded combination bits;
- b)  $p_{12}$  – Probability of transition from state 1 to state 2;
- c)  $p_{24}$  – Probability of transition from state 2 to state 4;
- d)  $p_{31}$  – Probability of transition from state 3 to state 1;
- e)  $p_{43}$  – is the probability of transition from state 4 to state 3;
- f)  $p_{2o}$  – probability of error in case 2;
- g)  $p_{3o}$  – probability of error in case 3;
- h)  $ticks$  – a variable used to increase the accuracy of modeling;



In st23 / mode, the need to step from state 2 to state 3 or state 4 is determined. If the condition  $p < p_{24}$  is satisfied, then the transition to st4 / occurs. Otherwise the system will start processing in st3 / mode.

st4 / mode correspond to position 4 in the Petrovich model. This condition includes 2 successor states: st41 / and st42 /. In this case, no errors occur.

In st41 / mode, the values of the transmitted bit counter (**ns**) and the correctly transmitted bit counter (**do**) are increased by one. If the value of the transmitted bit counter is less than the length of the coded combination ( $ns < n$ ), a transition to st42 / occurs. Otherwise, the value of the Do value counter **T** is increased by one, the output variable **D<sub>0</sub>** is assimilated to the **do** value, and the transition to the mode *begin* / processes.

The need to step from state 4 to state 3 is determined in st42 / mode. If the  $p < p_{43}$  condition is satisfied, the transition to the st3 / state occurs. Otherwise the system will remain in st4 / mode (i.e. it will process in st41 / mode).

The cases of st1 / and st3 / correspond to the cases 1 and 3 of the Petrovich model.

To operate the model the followings are required:

- “Constant value” parameter amount is 8 in “Nr” block;
- “Constant value” parameter amount is 0.89782886 in “Pcr” block;
- “Constant value” parameter amount is 0.10217114 in “Ped” block.

When modeling process is finished, the number of retransmission amount is entered in repeats/mat file, the followings appear in “Display” block:

- The total number of received frames (**RF**);
- The number of received correct register (**CR**);
- The number of dropped frames (**DF**);
- The number of error units (**EU**).

This model formula is used to identify the empiric probability of invalidity of units.

$$P_{eo}^e = \frac{EU}{RF}$$

The program registered in Listing 1 can be used to identify the parameter of the amount of model retransmission.

*Listing 1 - A program to determine the selection parameters*

```

Kmax = 8; %
Load ('file_name'); %
Length_TR = length (TR (1, :));
R = 1: length_TR;
T = 0;
for I = 1: length_TR,
    if T < TR(2, I),
        T = TR(2, I);
        R(T) = TR(3, I);
    end;
end;
x = R(1 : T);
x = sort(x);
n = length(x);
f = n - 1;
xmin = x(1);
xmax = x(n);
fprintf(' Sample size = %d\n', n);

```



```

fprintf('Degrees of freedom =% d \ n', f)
fprintf('Minimum value =% g \ n', xmin);
fprintf('Maximum value = %g\n\n', xmax);
k = 0:Kmax; %
q = -1:Kmax-1; %
% determination of empirical probability
N = hist(x, k);
z = N./n;
y(1) = 0;
for I = 2:Kmax+1,
    y(I) = y(I-1) + z(I-1);
end
subplot(2, 1, 1);
hist(x, k);
title('Histogram of the distribution of the number of repetitions);
xlim([-1, Kmax+1]);
subplot(2, 1, 2);
stairs(q, y);
title('The empirical distribution function of the number of repetitions ');
ylim([0, 1.1]);
xlim([-1, Kmax+1]);
disp(' The empirical probability of the number of repetitions k:');
for I = 0: Kmax,
    fprintf('P(%g) = %g\n', I, z(I+1));
end
Mx = mean(x);
Sx = std(x);
Dx = Sx^2;
Ax = sum((x - Mx).^3)/(n - 1)/Sx^3;
Ex = sum((x - Mx).^4)/(n - 1)/Dx^2-3;
Disp(' ');
disp(' Selected distribution parameters:');
fprintf('Expected value= %g\n', Mx);
fprintf('Standard deviation= %g\n', Sx);
fprintf('Variance =% g \ n', Dx);
fprintf('Asymmetry =% g \ n', Ax);
fprintf('Excess =% g \ n \ n \ n \ n', Ex);

```

In order to determine the adequacy of the model, the results obtained during the experiment can be compared with the theoretical values shown in (6.8) and (6.9).

### Conclusion

The following results were obtained during the study.

The empiric probability of residual invalidity is:

$$P_{eo}^e = \frac{EU}{RF} = \frac{0}{134681} = 0.$$

The theoretical probability of residual invalidity is:

$$P_{eo}^t = \frac{P_{oe}^K \cdot (1 - (P_{oo}^K)^{N_p - 1})}{1 - P_{oo}^K} = \frac{2.9286 \cdot 10^{-9} \cdot (1 - 0.10217114^{999})}{1 - 0.1217114} = 3.2619 \cdot 10^{-9}$$

The observations show that the theoretical value of the probability of residual invalidity is very low and almost zero. Therefore, it can be said that in this example, the theoretical and empirical values are consistent.

The empirical parameter of the distribution of the number of transmissions:

Sampling size = 96334

Number of independent levels = 96333

Minimum value = 0

Maximum value = 32

Mathematical expectation = 3.67983

Average squared deviation = 5.88165

Dispersion = 34.5938

Asymmetry = 2.25047

Excess = 5.57401

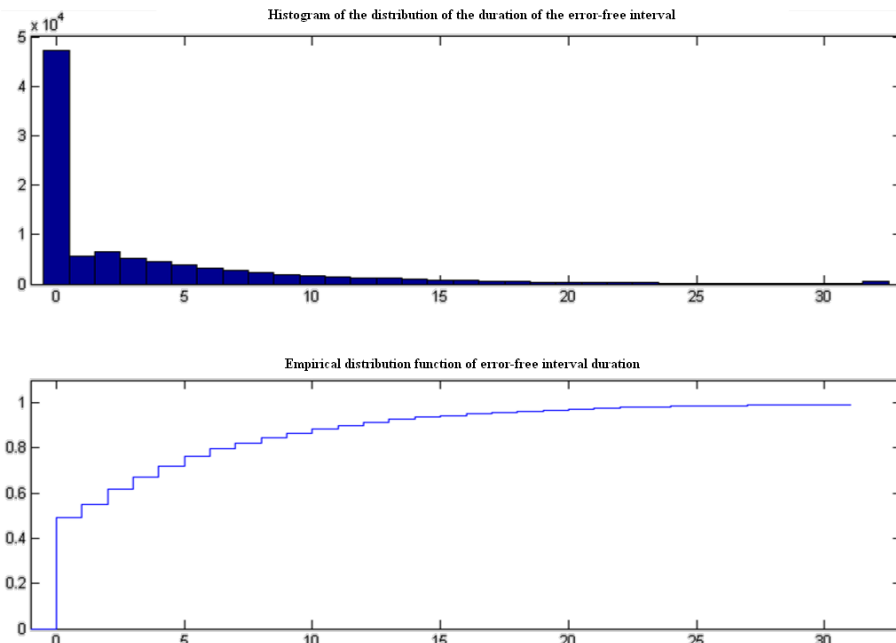


Figure 4. Empirical distribution function and bar chart of error-free interval duration.

Table 1.

*k* theoretical and empirical probabilities of repetition.

Number of retransmissions	Theoretical	Imitational
0	0.89782886	0.897907
1	0.091732198	0.0916239
2	0.009372383	0.00937771
3	0.000957587	0.00100979
4	$9.78378 \cdot 10^{-5}$	$7.42495 \cdot 10^{-5}$
5	$9.9962 \cdot 10^{-6}$	$7.42495 \cdot 10^{-6}$
6	$1.02132 \cdot 10^{-6}$	0
7	$1.0435 \cdot 10^{-7}$	0
8	$1.18747 \cdot 10^{-8}$	0

In summary, a discrete communication channel can be used to study independently by the technical engineers in the field of telecommunications technology using virtual simulation modeling. As it is not always possible for engineers to assemble and use telecommunications equipment at home, and this program analyzes the performance of discrete channels at home, the probabilistic characteristics of a discrete channel are standard elements and blocks of the Simulink section of MATLAB. allows you to do it independently. This process can save engineers real-time mode and increase and strengthen their work efficiency skills by 60-70%. In turn, the formation of remote monitoring of the work process of the object helps to bring the modern communication system to a new stage of development.

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