

Markovian Transition Probability Model

- Multi-Stage Exponential Hazard Model (Likelihood Function) -

Program User's Guide (Draft)

Developed by Kyoto University

1. Overview

The Asset Management of infrastructure is important to determine the optimal repair and maintenance strategy to maximize life cycle cost reduction. The predicted demand at the time of construction and repair facilities in the future, be required to formulate a budget plan for the maintenance and repair of infrastructure facilities. The models for deterioration prediction of infrastructure, play an important role to predict the demand for maintenance and lifecycle costs.

The objective of this program is to provide the fundamental information to make decisions of infrastructure management to administrators.

2. Program Language

This Program was developed by Fortran.

3. Usage

3-1. Copy of program

Create the new folder under C drive, and create folders named "input" and "output" under created new folder. (See Figure.1)

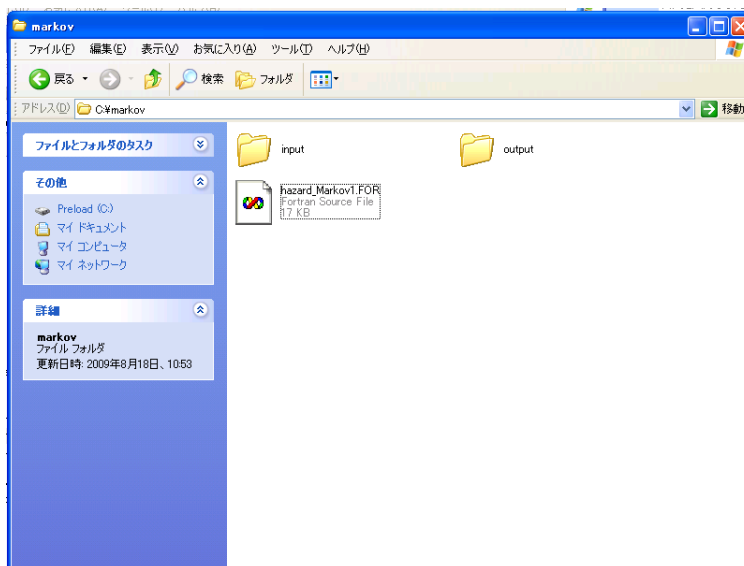


Figure.1 Folders for this program

3-2. Components of Input data

The file of inputdata.csv, should include the information of "Initial state of the infrastructure on the first inspection", "Next state of the infrastructure on the second inspection", "Interval (Duration) in two (2) inspections", "Constant value (1)" and specific

vectors in the first line. (Shown in Figure 2; note that the program will not work, if you input the data from first column.)

The “Interval in two inspections” can apply each time unit such as year, day, week etc., however, you must dominate the whole of time unit through this analysis. The number of specific vectors in this CSV file (inputdata.csv) conforms to number of MMAX in the program (hazard_Markov1.FOR).

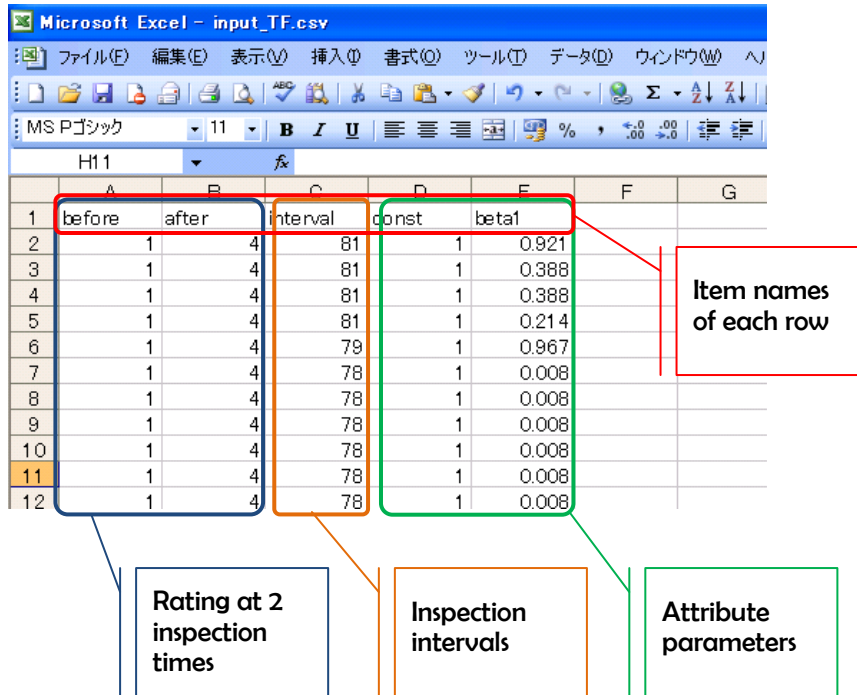


Figure.2 Components of Input Data

4. Components of Module

The first part of this program has written Module. In Figure.3, the red bold lines indicate the important part in the module. The meaning of word refer to following explanations:

(1)

- JMAX Number of Ratings
- MMAX Number of Attribute parameters
- TOTALDATA Number of Samples

(2)

- D1 Number of Erasing parameters
- DEL(D1) Numbers of Erasing parameter

- (3)
B1, J1 Initial value of unknown parameters
- (4)
FILE1 File name of Input data
FILE1000, FILE1001, FILE1002, FILE1003
 File names of Output files
- (5)
X1 Value of “Attribute parameters” to define and calculate the transition probability matrix
Z1 Value of “Estimating duration” to define and calculate the transition probability matrix

```

*****
*   Markov Transition Probability Model
*****
MODULE VARIABLE
  INTEGER, PARAMETER:: JMAX=4, MMAX=2
  !
  INTEGER, PARAMETER:: TOTALDATA=220
  !
  !
  INTEGER, PARAMETER:: TIMEMAX=100
  INTEGER, PARAMETER:: dimN=(JMAX-1)*MMAX
  !
  !
  !
  INTEGER, PARAMETER:: D1=2
  INTEGER, PARAMETER:: redimN=dimN-D1
  !
  INTEGER DEL(D1)
  DATA DEL/4,6/ !
  !
  REAL*8, PARAMETER:: B1=1.1D-02, J1=3.0D-03
  !
  REAL*8, PARAMETER:: B1=1.1D-03, J1=3.0D-03
  !
  !
  CHARACTER(LEN=20), PARAMETER:: FILE1="input¥input_TF.csv"
  CHARACTER(LEN=13), PARAMETER:: FILE1000="output¥df2.csv"
  CHARACTER(LEN=18), PARAMETER:: FILE1001="output¥beta-t2.csv"
  CHARACTER(LEN=18), PARAMETER:: FILE1002="output¥hazard2.csv"
  CHARACTER(LEN=18), PARAMETER:: FILE1003="output¥avlife2.csv"
  !
  !
  REAL*8:: THETA(JMAX)
  REAL*8:: THETASA(JMAX, JMAX)
  INTEGER:: MAXTHETA
  CHARACTER CH
  !
  !
  REAL*8 X1(MMAX)
  REAL Z1
  !
  DATA X1/1.0, 1.0/
  DATA Z1/2.0/
  !
END MODULE
  
```

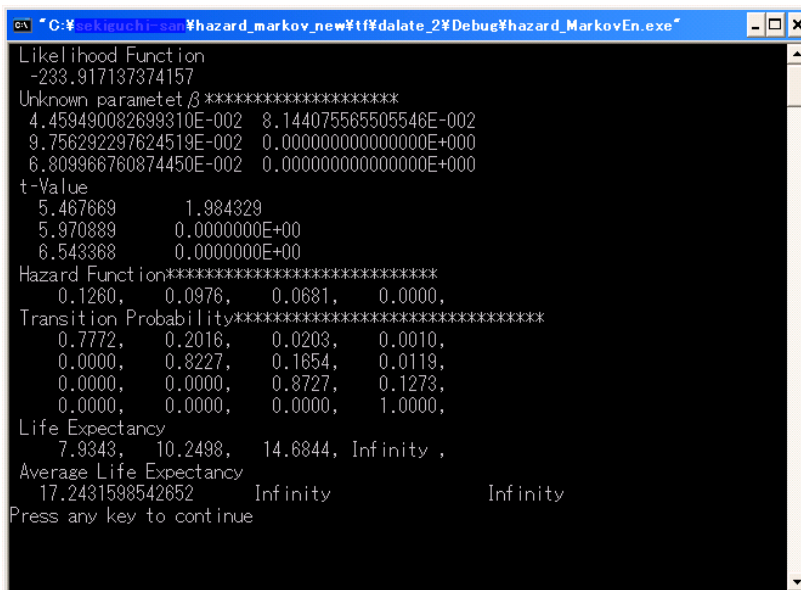
The screenshot shows the Fortran code with the following annotations:

- (1)** Points to the parameter declarations: `INTEGER, PARAMETER:: JMAX=4, MMAX=2` and `INTEGER, PARAMETER:: TOTALDATA=220`.
- (2)** Points to the parameter declarations: `INTEGER DEL(D1)` and `DATA DEL/4,6/ !`.
- (3)** Points to the parameter declarations: `REAL*8, PARAMETER:: B1=1.1D-02, J1=3.0D-03` and `REAL*8, PARAMETER:: B1=1.1D-03, J1=3.0D-03`.
- (4)** Points to the character parameter declarations: `CHARACTER(LEN=20), PARAMETER:: FILE1="input¥input_TF.csv"`, `CHARACTER(LEN=13), PARAMETER:: FILE1000="output¥df2.csv"`, `CHARACTER(LEN=18), PARAMETER:: FILE1001="output¥beta-t2.csv"`, `CHARACTER(LEN=18), PARAMETER:: FILE1002="output¥hazard2.csv"`, and `CHARACTER(LEN=18), PARAMETER:: FILE1003="output¥avlife2.csv"`.
- (5)** Points to the data declarations: `DATA X1/1.0, 1.0/` and `DATA Z1/2.0/`.

Figure.3 Components of Module

5. Components of Output Data

As shown in (4) of Figure.3, this program create the new files of df.csv, beta-t.csv, hazard.csv and avlife.csv, and output Hazard function in df.csv, value of unknown parameters and t-value in beta-t.csv, hazard function and Markovian transition probability in hazard.csv, and average life expectancy in each state of deterioration, respectively. The sample display is shown in Figure.4. The value of Likelihood function and life expectancy will display as well as outputs which include in files.



```
C:\Program Files\Kikuchi-san\hazard_markov_new\tdalate_2\Debug\hazard_MarkovEn.exe
Likelihood Function
-233.917137374157
Unknown parameter beta *****
4.459490082699310E-002  8.144075565505546E-002
9.756292297624519E-002  0.000000000000000E+000
6.809966760874450E-002  0.000000000000000E+000
t-Value
5.467689      1.984329
5.970889      0.0000000E+00
6.543368      0.0000000E+00
Hazard Function*****
0.1260, 0.0976, 0.0681, 0.0000,
Transition Probability*****
0.7772, 0.2016, 0.0203, 0.0010,
0.0000, 0.8227, 0.1654, 0.0119,
0.0000, 0.0000, 0.8727, 0.1273,
0.0000, 0.0000, 0.0000, 1.0000,
Life Expectancy
7.9343, 10.2498, 14.6844, Infinity ,
Average Life Expectancy
17.2431598542652      Infinity      Infinity
Press any key to continue
```

Figure.4 Output Display

6. Flowchart of Program

(1) Overview of Program

This program is predicted approximation solution by Newton-Raphson method

(2) Subroutine

This program uses several subroutines. The interconnectedness of Input data, Main program, Subroutine and Output data is shown in Figure-5.

① NEWTON_RAPHSON

Subroutine to calculate the solutions of simultaneous nonlinear equation using Newton-Raphson method

② FIRST_DEFFERENTIAL

Subroutine to calculate the solutions of first deferential of legalism of transition

probability

③ HESSIAN

Subroutine to calculate the second differential

④ PRINT1

Subroutine to display hazard function and Markovian transition probability matrix

⑤ ELIFE

Subroutine to calculate average life expectancy

⑥ DEL MATRIX

Subroutine to erase the parameters which the value of all row of column become Zero

⑦ MATRIX1

Subroutine to calculate the solutions of simultaneous equation using LU breakdown

⑧ MATRIX INVERSE

Subroutine to calculate the inverse matrix using Perfection Pivot method

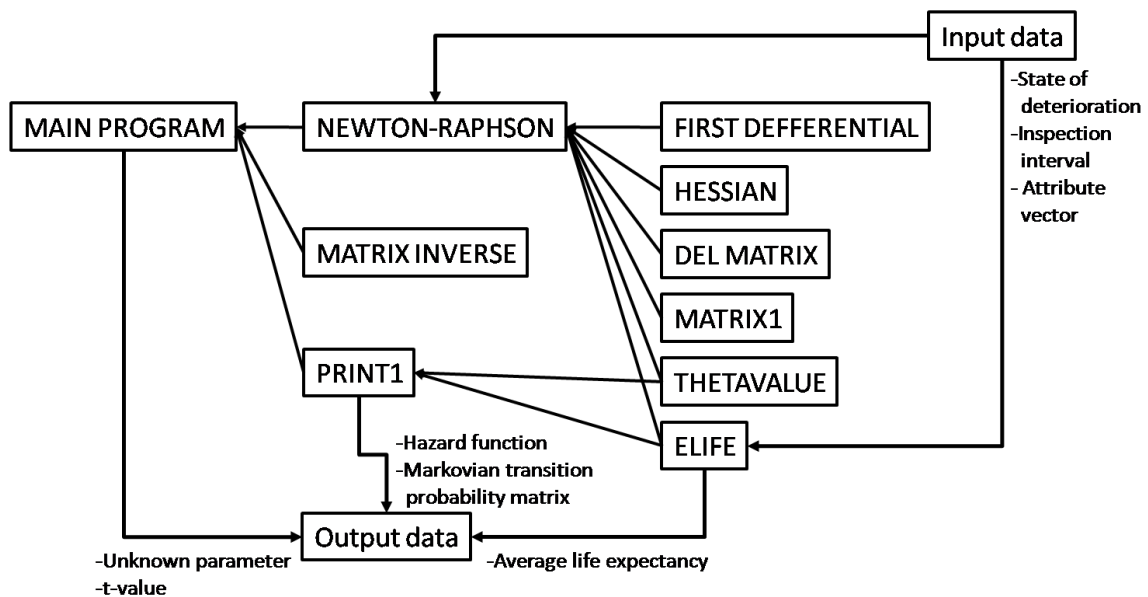


Figure.5 Interconnectedness of Input data, Main program, Subroutine and Output data