

Analysis the Increment of COVID-19 Cases in Indonesia with One of Multivariate Markov Chain Model Parameter

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ABSTRACT

The global cases of COVID-19 pandemic extensively increase as in Indonesia as the first two confirmed (positive) cases were reported in 2nd of March 2020 and followed by the first mortality case in 9 days afterwards, 11th of March 2020. In latest situation, the last data collection by author in 5th of November 2020 14,348 died and 425,796 COVID-19 confirmed cases were recorded. Therefore, in this study the author will construct a Multivariate Markov-Chain Model to estimate the increase in COVID-19 patients for confirmed, recovered, and died cases. Multivariate Markov chain is popular model for forecasting by observing current state in various applications. This model is compatible with 3 data sequences (patient types) defined as recovered patient, confirmed, and died with 6 conditions (zero, least, less, fair, ample, and massive). As the result, this study shows transition probability matrix with 3x3 dimension where each element containing 6x6 conditions. The highest transition probability value for the increment of COVID-19 cases in Indonesia on March 11 to November 5, 2020, occurred in a transition from confirmed to confirmed patient with conditions from ample to ample, which had the highest probability value 0.8571 and the highest frequency 78 times.

Keywords: *COVID-19, Multivariate Markov-Chain model, the transition probability matrix.*

1. INTRODUCTION

According to the website of the Ministry of Health of the Republic of Indonesia, Coronavirus is a large family of viruses that cause disease in humans and animals. In humans, this virus usually causes respiratory tract infections, from the common cold to serious illnesses such as Middle East Respiratory Syndrome (MERS) and Severe Acute Respiratory Syndrome (SARS). A new type of coronavirus that was discovered in humans since the outbreak occurred in Wuhan China, in December 2019, was then named Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-COV2), and causes Coronavirus Disease-2019 (COVID-19). In Indonesia, the COVID-19 case began to be recorded on March 2, 2020 with 2 confirmed patient cases then the first patient died was recorded on March 11, 2020. The latest condition, namely the last day of data collection on November 4 2020, recorded 14,348 people died and 425,796 people were confirmed COVID-19. COVID-19 cases in Indonesia continue to increase every day, so that

the Government has imposed PSBB (Large-Scale Social Restrictions) in certain areas.

Look at the situation, it is very important to do an analysis of COVID-19 data in Indonesia. Therefore, the author with the scientific basis of Statistical Mathematics will build a multivariate Markov chain model that can estimate future conditions by observing current conditions. The Markov chain was first coined by a Russian professor named Andrei A. Markov (1856-1922). The following is Markov's statement which is later referred to as the Markov trait (Markovian Property): "The conditional probability of a future event, knowing past events and present events, is independent of past events and only dependent on present events"[5]. The multivariate Markov chain model was used because it consisted of 3 data sequences (patient types), namely patients recovered, confirmed patients, and patients died with 6 conditions.

The problem in this study is how to build a transition probability matrix on a discrete Markov chain. Furthermore, the transition opportunity matrix is

analyzed to estimate the opportunities for COVID-19 in Indonesia in the future.

2. MATERIALS AND METHOD

2.1. Materials

In this paper, author use the COVID-19 data in Indonesia provided from The Ministry of Health of the Republic of Indonesia (Kemenkes RI) [3] to analysis the data. Every day, they record COVID-19 data in Indonesia. The duration of the data used was 240 days from March 11, 2020 to November 5, 2020, where March 11, 2020, was the first day a patient died in Indonesia. The data analyzed was data on the increase in the number of COVID-19 patients in Indonesia every day for 3 types of patients, namely recovered (1), the confirmed (2), and died (3) with 6 conditions ($m = 6$), that is zero (1st state), least (2nd state), less (3rd state), fair (4th state), ample (5th state), and massive (6th state). Based on the data on the increase per day, the condition limitation for recovered and confirmed patients is the same, namely zero for 0 people, least for 1 to 100 people, less for 101 to 500 people, fair for 501 to 1500 people, ample for 1501 to 4000 people, and massive for 4001 people and above. Whereas for patients who die because the data movement is smaller than that of recovered and confirmed patient, then the condition limits follow, namely zero for 0 people, least for 1 to 25 people, less for 26 to 50 people, fair for 51 to 100 people, ample for 101 to 150 people, and massive for 151 people and above.

2.2. Method

2.2.1. The Definition of Markov-Chain

The Markov chain is a stochastic process $\{X_n, n = 0, 1, \dots\}$ that has a state space in the form of a finite set or a spelled set. For example, at time n , the process is in state k , then it can be written $X_n = k$. What is meant by stochastic processes is a collection of random variables where n represents the time index. Thus, the Markov chain can be written as follows:

$$P \left\{ \begin{array}{l} \underbrace{X_{n+1} = j}_{\text{future events}} \mid \underbrace{X_0 = k_0, X_1 = k_1, \dots, X_{n-1} = k_{n-1}}_{\text{past events}}, \\ \underbrace{X_n = k}_{\text{current events}} \end{array} \right\} \quad (1)$$

$$= P \{ X_{n+1} = j \mid X_n = k \} = P_{jk}$$

for all $k_0, k_1, \dots, k_{n-1}, k, j$ and all $n \geq 0$.

Based on equation (1), the conditional probability of all future events X_{n+1} , given the past events X_0, X_1, \dots, X_{n-1} and the current events X_n , are independent past events, and only depends on current

events [4]. Probability P_{jk} is the probability of transition to state j given the current events, namely state k . The following are properties possessed by P_{jk} :

$$\sum_{k=1}^m P_{jk} = 1, P_{jk} \geq 0, j = 1, 2, \dots, m$$

2.2.2. Construction of Multivariate Markov Chain Models

In this multivariate Markov chain model, [1] it is assumed that there are s categories of categorical data (patient types), each of which has m states (for example: many, few, etc.).

$$M = \{1, 2, \dots, m\}$$

Let $\mathbf{x}_n^{(j)}$ be the state probability vector of the j th sequence (patient types) at time n . If at the n th time, the j th sequence (patient types) is in state l , then it can be written:

$$\mathbf{x}_n^{(j)} = \mathbf{e}_l = (0, \dots, 0, \underbrace{1}_{\text{state } l}, 0, \dots, 0)^T.$$

In constructing the multivariate Markov chain model, the following equation is assumed:

$$\mathbf{x}_{n+1}^{(j)} = \sum_{k=1}^s \lambda_{jk} \mathbf{P}^{(jk)} \mathbf{x}_n^{(k)}, \text{ for } j = 1, 2, \dots, s \quad (2)$$

where $\lambda_{jk} \geq 0, 1 \leq j, k \leq s$,

$$\text{and } \sum_{k=1}^s \lambda_{jk} = 1, \text{ for } j = 1, 2, \dots, s$$

Thus, based on equation (2), the distribution of the probability states of the sequence (patient type) j at time $(n + 1)$ depends on the states of the sequence (patient type) j and k at time n . Here λ_{jk} is the probability weight which includes the effect of the sequence state (patient type) k to j . As $\mathbf{P}^{(jk)}$ is the probability of the sequence state (patient type) k to j , and $\mathbf{x}_n^{(k)}$ is the probability of the sequence state (patient type) k at time n . The following is writing in matrix:

$$\mathbf{x}_{n+1} = \begin{pmatrix} \mathbf{x}_{n+1}^{(1)} \\ \mathbf{x}_{n+1}^{(2)} \\ \vdots \\ \mathbf{x}_{n+1}^{(s)} \end{pmatrix} = \begin{pmatrix} \lambda_{11} \mathbf{P}^{(11)} & \lambda_{12} \mathbf{P}^{(12)} & \dots & \lambda_{1s} \mathbf{P}^{(1s)} \\ \lambda_{21} \mathbf{P}^{(21)} & \lambda_{22} \mathbf{P}^{(22)} & \dots & \lambda_{2s} \mathbf{P}^{(2s)} \\ \vdots & \vdots & \ddots & \vdots \\ \lambda_{s1} \mathbf{P}^{(s1)} & \lambda_{s2} \mathbf{P}^{(s2)} & \dots & \lambda_{ss} \mathbf{P}^{(ss)} \end{pmatrix} \begin{pmatrix} \mathbf{x}_n^{(1)} \\ \mathbf{x}_n^{(2)} \\ \vdots \\ \mathbf{x}_n^{(s)} \end{pmatrix} \quad (3)$$

$$\equiv \mathbf{Q} \mathbf{x}_n$$

2.2.3. Estimation of Model Parameters

In this paper, we estimate the transition probability matrix $\mathbf{P}^{(jk)}$ for each data sequence. Here are the steps for finding the estimated transition probability matrix parameters $\mathbf{P}^{(jk)}$ by the following method [2]:

- Calculate the transition frequency $f_{i_jk}^{(jk)}$ from a state both in the same data sequence, or in different data sequence.

- Save as the transition frequency matrix $\mathbf{F}^{(jk)}$:

$$\mathbf{F}^{(jk)} = \begin{pmatrix} f_{11}^{jk} & f_{21}^{jk} & \dots & f_{m1}^{jk} \\ f_{12}^{jk} & f_{22}^{jk} & \dots & f_{m2}^{jk} \\ \vdots & \vdots & \ddots & \vdots \\ f_{1m}^{jk} & f_{2m}^{jk} & \dots & f_{mm}^{jk} \end{pmatrix}$$

with m the number of state.

- Calculate the transition probability from the k th state to the j th state by normalizing, so that the transition probability $p_{i_jk}^{(jk)}$ is obtained:

$$p_{i_jk}^{(jk)} = \begin{cases} \frac{f_{i_jk}^{(jk)}}{\sum_{i_k=1}^m f_{i_jk}^{(jk)}} & \text{if } \sum_{i_k=1}^m f_{i_jk}^{(jk)} \neq 0 \\ 0 & \text{otherwise} \end{cases}$$

- Save as the transition probability matrix form $\mathbf{P}^{(jk)}$:

$$\mathbf{P}^{(jk)} = \begin{pmatrix} p_{11}^{jk} & p_{21}^{jk} & \dots & p_{m1}^{jk} \\ p_{12}^{jk} & p_{22}^{jk} & \dots & p_{m2}^{jk} \\ \vdots & \vdots & \ddots & \vdots \\ p_{1m}^{jk} & p_{2m}^{jk} & \dots & p_{mm}^{jk} \end{pmatrix}$$

with m the number of state.

3. RESULTS AND DISCUSSION

3.1. The Transition Frequency Matrix

\mathbf{F} is the transition frequency matrix for 3 types of patients ($s = 3$), that is recovered (1), confirmed (2) and died (3) in six states ($m = 6$), zero (1st state), least (2nd state), less (3rd state), fair (4th state), ample (5th state), and massive (6th state):

$$\mathbf{F} = \begin{pmatrix} \mathbf{F}^{(11)} & \mathbf{F}^{(12)} & \mathbf{F}^{(13)} \\ \mathbf{F}^{(21)} & \mathbf{F}^{(22)} & \mathbf{F}^{(23)} \\ \mathbf{F}^{(31)} & \mathbf{F}^{(32)} & \mathbf{F}^{(33)} \end{pmatrix}$$

where

$$\mathbf{F}^{(jk)} = \begin{pmatrix} f_{11}^{(jk)} & f_{21}^{(jk)} & f_{31}^{(jk)} & f_{41}^{(jk)} & f_{51}^{(jk)} & f_{61}^{(jk)} \\ f_{12}^{(jk)} & f_{22}^{(jk)} & f_{32}^{(jk)} & f_{42}^{(jk)} & f_{52}^{(jk)} & f_{62}^{(jk)} \\ f_{13}^{(jk)} & f_{23}^{(jk)} & f_{33}^{(jk)} & f_{43}^{(jk)} & f_{53}^{(jk)} & f_{63}^{(jk)} \\ f_{14}^{(jk)} & f_{24}^{(jk)} & f_{34}^{(jk)} & f_{44}^{(jk)} & f_{54}^{(jk)} & f_{64}^{(jk)} \\ f_{15}^{(jk)} & f_{25}^{(jk)} & f_{35}^{(jk)} & f_{45}^{(jk)} & f_{55}^{(jk)} & f_{65}^{(jk)} \\ f_{16}^{(jk)} & f_{26}^{(jk)} & f_{36}^{(jk)} & f_{46}^{(jk)} & f_{56}^{(jk)} & f_{66}^{(jk)} \end{pmatrix}$$

for $j = 1, 2, 3$ and $k = 1, 2, 3$

Assume that $\mathbf{F}^{(13)}$ is the identity matrix, because there is no transition from died patient (3) to recovered patient (1). Likewise, with $\mathbf{F}^{(21)}$, $\mathbf{F}^{(23)}$, and $\mathbf{F}^{(31)}$ are identity matrices because they are not possible.

The following are the results of calculating the transition frequency using the MATLAB software:

$$\mathbf{F}^{(11)} = \begin{pmatrix} 0 & 4 & 0 & 0 & 0 & 0 \\ 4 & 38 & 5 & 0 & 0 & 0 \\ 0 & 6 & 26 & 5 & 0 & 0 \\ 0 & 0 & 6 & 38 & 6 & 0 \\ 0 & 0 & 0 & 7 & 68 & 11 \\ 0 & 0 & 0 & 0 & 11 & 4 \end{pmatrix} \quad \mathbf{F}^{(12)} = \begin{pmatrix} 0 & 4 & 0 & 0 & 0 & 0 \\ 2 & 6 & 38 & 1 & 0 & 0 \\ 0 & 0 & 19 & 18 & 0 & 0 \\ 0 & 0 & 0 & 31 & 19 & 0 \\ 0 & 0 & 0 & 1 & 64 & 21 \\ 0 & 0 & 0 & 0 & 8 & 7 \end{pmatrix} \quad \mathbf{F}^{(13)} = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix}$$

$$\mathbf{F}^{(21)} = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix} \quad \mathbf{F}^{(22)} = \begin{pmatrix} 0 & 2 & 0 & 0 & 0 & 0 \\ 2 & 6 & 1 & 0 & 0 & 0 \\ 0 & 2 & 50 & 5 & 0 & 0 \\ 0 & 0 & 6 & 40 & 5 & 0 \\ 0 & 0 & 0 & 6 & 78 & 7 \\ 0 & 0 & 0 & 0 & 8 & 21 \end{pmatrix} \quad \mathbf{F}^{(23)} = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix}$$

$$\mathbf{F}^{(31)} = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix} \quad \mathbf{F}^{(32)} = \begin{pmatrix} 0 & 4 & 0 & 0 & 0 & 0 \\ 2 & 6 & 41 & 8 & 0 & 0 \\ 0 & 0 & 14 & 27 & 6 & 0 \\ 0 & 0 & 2 & 16 & 55 & 14 \\ 0 & 0 & 0 & 0 & 30 & 13 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix} \quad \mathbf{F}^{(33)} = \begin{pmatrix} 1 & 3 & 0 & 0 & 0 & 0 \\ 3 & 40 & 12 & 2 & 0 & 0 \\ 0 & 13 & 21 & 13 & 0 & 0 \\ 0 & 2 & 14 & 55 & 16 & 0 \\ 0 & 0 & 0 & 16 & 26 & 1 \\ 0 & 0 & 0 & 0 & 1 & 0 \end{pmatrix}$$

On the transition frequency matrix \mathbf{F} , we can see the highest transition frequency value in each transition frequency matrix, as follows:

- The transition frequency matrix from recovered patient to the recovered patient $\mathbf{F}^{(11)}$, the highest value is in 5th row and 5th column $f_{55}^{(11)} = 68$. This shows that the highest transition frequency value in the transition frequency matrix from recovered patient (1) to recovered patient (1) tends to be constant, from ample condition (5th state) to ample condition (5th state).
- The transition frequency matrix from confirmed patient to recovered patient $\mathbf{F}^{(12)}$, the highest value is in 5th row and 5th column $f_{55}^{(12)} = 64$. This shows that the highest transition frequency value in the transition frequency matrix from confirmed patient (2) to recovered patient (1) tends to be constant, from ample condition (5th state) to ample condition (5th state).
- The transition frequency matrix from confirmed patient to confirmed patient $\mathbf{F}^{(22)}$, the highest value is

in 5th row 5 and column 5 $f_{55}^{(22)} = 78$. This shows that the highest transition frequency value in the transition frequency matrix from confirmed patient (2) to confirmed patient (3) tends to be constant, from ample condition (5th state) to ample condition (5th state).

- The transition frequency matrix from confirmed patient to died patient $\mathbf{F}^{(32)}$, the highest value is in 4th row and 5th column $f_{54}^{(32)} = 55$. This shows that the highest transition frequency value in the transition frequency matrix from confirmed patient (2) to died patient (3) has decreased, from ample condition (5th state) to fair condition (4th state).
- The transition frequency matrix from died patient to died patient $\mathbf{F}^{(33)}$, the highest value is in 5th row and 5th column $f_{44}^{(33)} = 55$. This shows that the highest transition frequency value in the transition frequency matrix from died patient (3) to died patient (3) tends to be constant, from fair condition (4th state) to fair condition (4th state).

3.2. The Transition Probability Matrix

\mathbf{P} is the transition probability matrix for 3 types of patients ($s = 3$), that is recovered (1), confirmed (2) and died (3) in six states ($m = 6$), zero (1st state), least (2nd state), less (3rd state), fair (4th state), ample (5th state), and massive (6th state):

$$\mathbf{P} = \begin{pmatrix} \mathbf{P}^{(11)} & \mathbf{P}^{(12)} & \mathbf{P}^{(13)} \\ \mathbf{P}^{(21)} & \mathbf{P}^{(22)} & \mathbf{P}^{(23)} \\ \mathbf{P}^{(31)} & \mathbf{P}^{(32)} & \mathbf{P}^{(33)} \end{pmatrix}$$

where

$$\mathbf{P}^{(jk)} = \begin{pmatrix} p_{11}^{(jk)} & p_{21}^{(jk)} & p_{31}^{(jk)} & p_{41}^{(jk)} & p_{51}^{(jk)} & p_{61}^{(jk)} \\ p_{12}^{(jk)} & p_{22}^{(jk)} & p_{32}^{(jk)} & p_{42}^{(jk)} & p_{52}^{(jk)} & p_{62}^{(jk)} \\ p_{13}^{(jk)} & p_{23}^{(jk)} & p_{33}^{(jk)} & p_{43}^{(jk)} & p_{53}^{(jk)} & p_{63}^{(jk)} \\ p_{14}^{(jk)} & p_{24}^{(jk)} & p_{34}^{(jk)} & p_{44}^{(jk)} & p_{54}^{(jk)} & p_{64}^{(jk)} \\ p_{15}^{(jk)} & p_{25}^{(jk)} & p_{35}^{(jk)} & p_{45}^{(jk)} & p_{55}^{(jk)} & p_{65}^{(jk)} \\ p_{16}^{(jk)} & p_{26}^{(jk)} & p_{36}^{(jk)} & p_{46}^{(jk)} & p_{56}^{(jk)} & p_{66}^{(jk)} \end{pmatrix}$$

for $j = 1, 2, 3$ and $k = 1, 2, 3$

The same is the case with the assumption at the transition frequency, the transition probability $\mathbf{P}^{(13)}$, $\mathbf{P}^{(21)}$, $\mathbf{P}^{(23)}$, $\mathbf{P}^{(31)}$ are identity matrices because they are not possible. The following are the results of calculating the transition probability using the MATLAB software:

$$\mathbf{P} = \begin{pmatrix} \mathbf{P}^{(11)} & \mathbf{P}^{(12)} & \mathbf{P}^{(13)} \\ \mathbf{P}^{(21)} & \mathbf{P}^{(22)} & \mathbf{P}^{(23)} \\ \mathbf{P}^{(31)} & \mathbf{P}^{(32)} & \mathbf{P}^{(33)} \end{pmatrix}$$

where

$$\mathbf{P}^{(11)} = \begin{pmatrix} 0 & 0.0833 & 0 & 0 & 0 & 0 \\ 1 & 0.7917 & 0.1351 & 0 & 0 & 0 \\ 0 & 0.125 & 0.7027 & 0.1 & 0 & 0 \\ 0 & 0 & 0.1622 & 0.76 & 0.0706 & 0 \\ 0 & 0 & 0 & 0.14 & 0.8 & 0.7333 \\ 0 & 0 & 0 & 0 & 0.1294 & 0.2667 \end{pmatrix},$$

$$\mathbf{P}^{(12)} = \begin{pmatrix} 0 & 0.4 & 0 & 0 & 0 & 0 \\ 1 & 0.6 & 0.6667 & 0.0196 & 0 & 0 \\ 0 & 0 & 0.3333 & 0.3529 & 0 & 0 \\ 0 & 0 & 0 & 0.6078 & 0.2088 & 0 \\ 0 & 0 & 0 & 0.0196 & 0.7033 & 0.75 \\ 0 & 0 & 0 & 0 & 0.0879 & 0.25 \end{pmatrix},$$

$$\mathbf{P}^{(22)} = \begin{pmatrix} 0 & 0.2 & 0 & 0 & 0 & 0 \\ 1 & 0.6 & 0.0175 & 0 & 0 & 0 \\ 0 & 0.2 & 0.8772 & 0.0980 & 0 & 0 \\ 0 & 0 & 0.1053 & 0.7843 & 0.0550 & 0 \\ 0 & 0 & 0 & 0.1177 & 0.8571 & 0.25 \\ 0 & 0 & 0 & 0 & 0.0879 & 0.75 \end{pmatrix},$$

$$\mathbf{P}^{(32)} = \begin{pmatrix} 0 & 0.4 & 0 & 0 & 0 & 0 \\ 1 & 0.6 & 0.7193 & 0.1569 & 0 & 0 \\ 0 & 0 & 0.2456 & 0.5294 & 0.0659 & 0 \\ 0 & 0 & 0.0351 & 0.3137 & 0.6044 & 0.5 \\ 0 & 0 & 0 & 0 & 0.3297 & 0.4643 \\ 0 & 0 & 0 & 0 & 0 & 0.0357 \end{pmatrix},$$

$$\mathbf{P}^{(33)} = \begin{pmatrix} 0.25 & 0.0517 & 0 & 0 & 0 & 0 \\ 0.75 & 0.6897 & 0.2553 & 0.0233 & 0 & 0 \\ 0 & 0.2241 & 0.4468 & 0.1512 & 0 & 0 \\ 0 & 0.0345 & 0.2979 & 0.6395 & 0.3721 & 0 \\ 0 & 0 & 0 & 0.1860 & 0.6046 & 1 \\ 0 & 0 & 0 & 0 & 0.0233 & 0 \end{pmatrix},$$

$$\mathbf{P}^{(13)} = \mathbf{P}^{(21)} = \mathbf{P}^{(23)} = \mathbf{P}^{(31)} = \begin{pmatrix} 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix}$$

Based on the value of the \mathbf{P} matrix above, we can see the greatest probability value in each column for each transition probability matrix, as follows:

- The first column (transition from the 1st state to all states): with the highest probability value of 1, is in the second row in matrix $\mathbf{P}^{(11)}$, meaning that there is a transition from 1st state to 2nd state. This shows that there is a transition from zero to the least condition (increased condition) at the transition probability matrix from recovered to recovered patient $\mathbf{P}^{(11)}$. The same applies to the transition probability matrix from confirmed to recovered patient $\mathbf{P}^{(12)}$, from confirmed to confirmed patient $\mathbf{P}^{(22)}$, from confirmed to died patient $\mathbf{P}^{(32)}$, and from dead to died patient $\mathbf{P}^{(33)}$. This implies that there is an increase in the number of cases from zero to the least condition in all the sequence (recovered, confirmed and died).
- Second column (transition from 2nd state to all states): with the greatest probability value of 0.7917, it is in the second row in the matrix $\mathbf{P}^{(11)}$, meaning that there is a transition from 2nd state to 2nd state. This shows that there is a transition from the least to the least condition (constant condition) at the transition probability matrix from recovered to recovered patient. The same thing happens to the transition probability matrix from confirmed to recovered patient $\mathbf{P}^{(12)}$, from confirmed to confirmed patient $\mathbf{P}^{(22)}$, from confirmed to died patient $\mathbf{P}^{(32)}$, from died to died patient $\mathbf{P}^{(33)}$. This interprets that the increase in the number of cases tends to remain at the least for all the sequence (recovered, confirmed and died).
- The third column (transition from 3rd state to all states): with the highest probability value 0.8772, it is in the third row in the matrix $\mathbf{P}^{(22)}$, meaning that there is a transition from 3rd state to 3rd state at the transition probability matrix from confirmed to confirmed patient. The same applies to $\mathbf{P}^{(11)}$ and $\mathbf{P}^{(33)}$. This shows that there is a transition from the less condition to less condition (constant condition) in the transition probability matrix from recovered to recovered patient $\mathbf{P}^{(11)}$, from confirmed to confirmed patient $\mathbf{P}^{(22)}$, and from died to died patient $\mathbf{P}^{(33)}$. Whereas the transition probability matrix from confirmed to recovered patient $\mathbf{P}^{(12)}$ and from confirmed to died patient $\mathbf{P}^{(32)}$, the greatest probability value is in the second row, meaning that there is a transition from 3rd state to 2nd state. This shows that there is a transition from the least condition to the less condition (decreased condition).
- Fourth column (transition from 4th state to all states): with the highest probability value of 0.7843, it is in the fourth row in the matrix $\mathbf{P}^{(22)}$, meaning that there is a transition from 4th state to 4th state at the transition probability matrix from confirmed to confirmed patient. The same applies to $\mathbf{P}^{(11)}$, $\mathbf{P}^{(12)}$, and $\mathbf{P}^{(33)}$. This shows that there is a transition from fair condition to fair condition (constant condition) at the transition probability matrix from recovered to recovered patient $\mathbf{P}^{(11)}$, from confirmed to confirmed patient $\mathbf{P}^{(22)}$, from confirmed to recovered patient $\mathbf{P}^{(12)}$, from died to died patient $\mathbf{P}^{(33)}$. Meanwhile, the transition probability matrix from confirmed to died patient $\mathbf{P}^{(32)}$ with the highest value in 3rd row, meaning that there is a transition from 4th state to 3rd state. This shows that there is a transition from fair condition to less condition (decreased condition).
- Fifth column (transition from 5th state to all states): with the greatest probability value 0.8571, it is in the fifth row in the matrix $\mathbf{P}^{(22)}$, meaning that there is a transition from 5th state to 5th state at the transition probability matrix from confirmed to confirmed patient. The same thing happened to $\mathbf{P}^{(11)}$, $\mathbf{P}^{(12)}$ and $\mathbf{P}^{(33)}$. This shows that there is a transition from the ample condition to the ample condition (constant condition) at the transition probability matrix from recovered to recovered patient $\mathbf{P}^{(11)}$, from confirmed to confirmed patient $\mathbf{P}^{(22)}$, from confirmed to confirmed patient $\mathbf{P}^{(22)}$, and from died to died patient $\mathbf{P}^{(33)}$. Meanwhile, the transition probability matrix from confirmed to died patient $\mathbf{P}^{(32)}$ the highest value is in the fourth row, meaning that there is a transition from 5th state to 4th state. This indicates that there is a transition from ample to fair condition (decreased condition).
- The sixth column (transition from 6th state to all states): with the highest probability value of 1, it is in the fifth row in the matrix $\mathbf{P}^{(33)}$, meaning that there is a transition from 6th state to 5th state on the transition probability matrix from died to died patient. The same thing happened to $\mathbf{P}^{(11)}$ and $\mathbf{P}^{(12)}$. This shows that there is a transition from massive condition to ample condition (decreased condition) at the transition probability matrix from recovered to recovered patient $\mathbf{P}^{(11)}$, from confirmed to recovered patient $\mathbf{P}^{(12)}$, and died to died patient $\mathbf{P}^{(33)}$. Whereas for the transition probability matrix from confirmed to confirmed patient $\mathbf{P}^{(22)}$, the greatest value is in the sixth row, meaning that there is a transition from 6th state to 6th state. This shows that there is a transition from massive state to massive state (the condition is constant). Finally, the transition probability matrix from confirmed to died patient $\mathbf{P}^{(32)}$ has the greatest value is in the fourth row, meaning that there is a transition from 6th state to 4th state. This shows that there is a transition from massive to fair condition (decreased condition).

4. CONCLUSION

The transition probability matrix is one of the parameters in the multivariate Markov chain model. The transition probability matrix can be calculated by calculating the transition frequency first, then normalizing it to the number of columns of each transition frequency matrix. The highest transition probability value for the increment of COVID-19 cases in Indonesia on March 11, 2020 to November 5, 2020, occurred in a transition from confirmed to confirmed patient with conditions from ample to ample, which had the highest probability value 0.8571 and the highest frequency 78 times.

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