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by Iceomia Ismi2

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Agent-Based Modelling and Simulation to Determine the Spread of COVID-19 Based on Human Behaviour in Indonesia

Abstract

The infectious disease Coronavirus Disease-2019 (COVID-19) spread around the world in early 2020. The speed of the virus's spread varies in different regions or countries depending on various factors such as the environment, human behaviour, and government intervention. Prediction of the spread of the Covid 19 virus has been carried out by many previous studies. Research that has been done is usually to determine the speed, peak, and predictions of the completion of this pandemic. However, research on the spread of COVID-19 using different individual behavioural approaches is still very limited. Modeling with different individual behaviours in the spread of COVID-19 can provide more realistic results. This study wants to know the relationship between individual behaviour and the spread of COVID-19 in Indonesia by using Agent-Based Modelling and Simulation, where this modelling emphasizes the influence of individual behaviour on emergencies in the form of the spread of COVID-19. The software used in this modeling is Netlogo 6.0. This study uses secondary data from various regions. This research presents simulations and information on various conditions of the spread of COVID-19 resulting from differences in individual behaviour. From this research, it is known that the implementation of health protocols by each individual and the policies implemented by the government has an impact on the spread of COVID-19.

Keywords: Agent-based behaviour, COVID-19, modelling, Indonesia, simulation

1. Introduction

The infectious disease causes by the coronavirus at the beginning of 2020 has caused disruption in many aspects. WHO named the disease as Coronavirus Disease-2019 (COVID-19) on February 11, 2020. (Wu et al., 2020). COVID-19 is a highly infectious disease caused by the advanced acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which caused in Wuhan, China (Shereen et al., 2020). This disease began to be known for its appearance in December 2019. The World Health Organization (WHO) declared COVID-19 a pandemic on March 11, 2020. Transmission of this virus is so easy that causes the spread of this virus to be very fast. Transmission of this virus can occur through droplets or direct contact (Wu et al., 2020)

The speed of spread of this virus is different in disparate regions or countries. This distinction can be influenced by various things, such as climate (Daryono, 2020), human behavior, and government policies. In Indonesia, the speed at which the spread of COVID-19 differs from region to region. For example, until October 2020 DKI Jakarta Province was in first place with the highest number of positive cases is 25.8% of all cases in Indonesia. East Java becomes the next province with the highest number of positive cases is 15,.8% of all cases (Satuan Tugas Penanganan COVID-19, 2020).

The Indonesia's government has declared a disaster emergency status from 29 February to 29 May 2020 regarding to this virus pandemic and urged the public to carry out social distancing and appeal not to leave the house (Buana, 2020). However, not all people obey this appeal. Some people who are very obedient by not leaving the house at all, some out of the house when there is an important activity, and there are those who continue to carry out activities as usual. This research wants to see the influence of these different individual behaviors and government policies on the spread of COVID-19.

1.1 Objectives

This study aims to understand the relationship between individual behaviour and the spread of COVID-19 in Indonesia by using Agent-Based Modelling and Simulation, where this modelling emphasizes the influence of individual behaviour on emergencies in the form of the spread of COVID-19.

2. Literature Review

A model is a representation of a real system, while modeling is the process of forming a model from a real system. Modeling can be used to determine the main goals and functions of a system, to understand the characteristics of the modeling system used, to determine the system model that will be used in building a system, and in order to analyze user needs in creating a system model. There are so many cases in everyday life that can be solved by modeling, for example, modeling the spread of disease.

Nuraini et al. (2020) have simulated the spread of COVID-19 in Indonesia based on initial endemic data. This model is based on the Richard Curve, which represents a modified logistic equation. Based on the model that has been made, the results show that the COVID-19 pandemic will end in April 2020 with more than 8,000 cases.

Ivorra et al. (2020) have developed a mathematical model for the spread of COVID-19. The model developed is the new θ-SEIHRD model (not SIR, SEIR, or other general-purpose models), which takes into account the specific features of this disease, such as the presence of undetected infections, different sanitation, and infectious conditions of hospitalized persons. This model is also able to predict hospital bed requirements. This research examines specific cases in China (including Mainland China, Macau, Hong Kong, and Taiwan, as did the WHO in its report on COVID-19), a country that is spreading the disease, and uses these reports to identify model parameters, which can be used to predict the spread of COVID-19 in other countries.

Agent-Based Modeling and Simulation (ABMS) is a computer-based simulation to model all the behavior of entities (agents) involved in the real world with the hope that interactions between entities can produce or describe the main characteristics that can be used as a tool for explanatory or predictive decisions in making decisions in the real world (Macal & North, 2010).

ABMS has been widely used to model various things such as logistical (Sopha et al., 2020), transportation (Arfani et al., 2019), economic (Worldailmi & Ismianti, 2020), political, and various other problems. ABMS can also be regarded as a tool that can be used to better understand the dynamics of an infectious disease outbreak because it can be influenced by many factors including vaccinations or immunity levels, population density, and population age structure (Hunter et al., 2018).

There are four main components of ABMS epidemiology, namely disease, society, transportation, and the environment (Hunter et al., 2017). When creating an agent-based model in infectious disease epidemiology, consideration should be made of how infectious diseases are transmitted between agents and how the disease develops in infected agents.

A study was established to simulate a measles outbreak that happened in Schull, Ireland, in 2012 (Hunter et al., 2018). Outbreaks were simulated in 33 different cities and correlations were sought between the model results and city characteristics, namely population, area, vaccination rate, and age structure. This simulation is to determine whether the model results are influenced by the interaction of city characteristics and decisions about agents in the model. The results show that the outbreak does not have a strong correlation with the main characteristics.

Human mobility is a critical element in understanding the spread of an epidemic. It means that precision in modeling human mobility is essential for examining large scale transmission of infectious diseases and improving epidemic control. Research conducted by Hackl & Dubernet (2019) was used to study seasonal influenza outbreaks in the metropolitan area of Zurich, Switzerland. The agent-based model observations were compared with the results from classical SIR models. This model is represented by a prototype that can be used to analyze several scenarios of cases of a disease spread on an urban scale, taking into account the various settings for different model parameters. The results of these simulations can help to improve understanding of the dynamics of disease spread and to make better steps towards epidemic prevention and control.

Saputra et al. (2018) has carried out an agent-based simulation modeling of the spread of tuberculosis. Contact with infected people, distance between healthy people and infected people, environmental factors, room temperature, and human immunity are various factors that affect the spread of this disease and are used in this modeling.

3. Methods

This research consists of 7 stages. Figure 1 shows the stages in this study. The first stage in this research is literature study. Literature studies were carried out to gather various information needed in this study, both information about the spread of COVID-19 and the latest research on COVID-19 simulations in Agent Based Modeling.

The next stage is to identify the main variables in this study. The main variables obtained are the implementation of health protocols and government policies. These two main variables were chosen because of these 2 things that are currently being done by the government and the people of Indonesia in dealing with COVID-19.

The next step is to define the Overview, Design concepts, and Details (ODD) Protocol in this model. The ODD protocol was created to make the model more understandable and more standardized. After the ODD protocol is determined, the next step is data collection. Data obtained from secondary data obtained from various sources.

After the data is collected, the next step is to start building the model. The model was made with the Netlogo 6.0.4 software. Netlogo is used because this software is free, easy to understand, can create complex model, and can be operated in various operating systems (Mac, Windows, Linux). After the model is built, verification and validation of the model is needed to see the correctness of the model created.

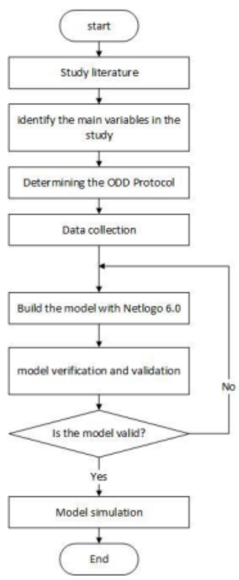

Figure 1. Step of the research

4. Data Collection

Data obtained from secondary data obtained from various sources.

5. Results and Discussion

5.1 ODD Protocol

Agent-based modeling is a computational model that allows describing the behavior of agents. Agents in the model can behave alone, collaborate, or compete between agents. The complexity of the actions carried out by each agent can range from simple things to stochastic behavior (Cuevas, 2020).

The ODD (Overview, Design Concept, and Details) protocol is used to create standardized descriptions made of individual-based and agent-based models. The main goal of ODD is to make the model description more complete and easier to understand (Grimm et al., 2010). Elements of ODD protocol in this study are described as follows.

1. Purpose

   The main aim of this research is to model the trend of the spread of COVID-19, which is influenced by individual behavior and government policies. While the sub-purposes of this research are to find out how people's habits or behavior affect the spread of COVID-19 and to find out how government policies have influenced the spread of COVID-19.

2. Entities, state variables, and scales

   Entities, state variables, and scales describe the types of agents, attributes, behaviors, and environment used in modelling can be seen in Table 1.

3. Process Overview and Scheduling

   The process overview and scheduling in this model include move, infect, dead, recover, and immune.

Table 1. Entities, Attributes, and Scale

Entities	Attributes	Scales
Mobile agents: People	- Ages - Colour: red (positive), green (healthy) Shape: person	1 tick = 1 day
Stationary Agent: Hospital	Shape: house	

4. Design Concepts

   a. Basic Principles

      The health protocol slider represents community obedience with the implementation of the health protocol. The health protocol in this model is the use of masks, washing hands, and social distance. The health protocol slider takes a range of 0 to 100%. 100% means that all citizens are implementing the health protocol, while 1% means that only 1% of the population is implementing the health protocol. Slider government policy represents government policy in limiting citizen activities. The policy in question is the existence of Large-Scale Social Restrictions (PSBB), closure of schools and campuses, closure of tourist attractions, restrictions on public transportation, etc. The government policy slider also uses a percentage, ranging from 0 to 100%. 100% means that the government strictly limits the activities of citizens or it can be called a total lockdown. 0% means that the government does not provide policies related to COVID-19 at all.

   b. Emergence

      The emergencies that result from this model are people who have tested positive for COVID-19 and people who have recovered from COVID-19.

   c. Objectives

      The objectives in this model is healthy and immune people.

d. Interaction
   The interactions that occur in this model are healthy people with positive people and positive people with health facilities or hospitals.
e. Stochasticity
f. The stochasticity used in this model is a random value constructed for the age and movement of people.
g. Observation
   In this model, the observed number of people who are sick, the number of people who recover (immunity), and the number of people who die.

5. Initialization
   The initialization used in this model is the number of people, number of hospitals, implementation of health protocols, and government policies in handling Covid-19.
6. Sub-models
   The sub-model in this model is to determine the effect of implementing health protocols on the spread of COVID-19 and knowing the effect of government policies on the spread of COVID-19.

5.2 Model

The model built in this study is a simple model made with 2 parameters that can be adjusted, namely health protocol and government policy. Figure 2 is a view of the model created.

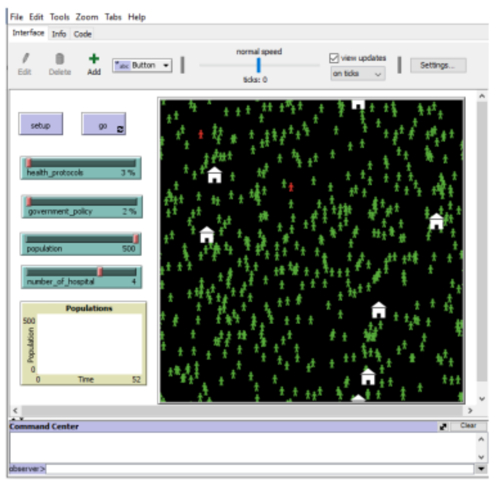

Figure 2. The COVID-19 spread model created with Netlogo 6.0.4

In this model, the population is given a range of 2 to 500. This is due to the limitations of the model so that it cannot provide the population size as in the real population. Hospitals in this model can be set from 0 to 6. Meanwhile, health protocol and government policy in this model can be set from 0 to 100%.

In this model, the population of people who are positive for COVID-19 is set at a value of 2. These 2 positive people can infect other people they meet randomly. Each person in this model has an age set at random. When an infected person is over 65 years of age, it is considered that the person will die. People who are positive if they are under 65 years old are considered to be cured after 4 weeks.

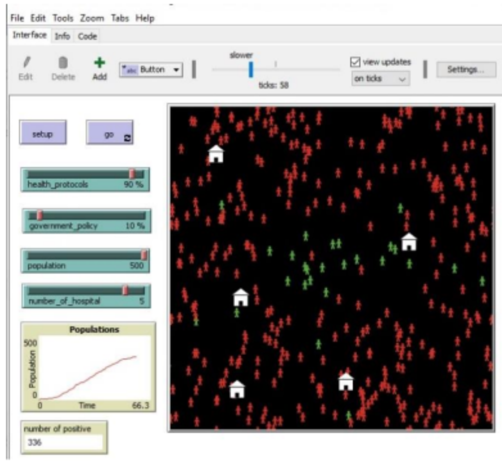

Figure 3. Simulation of condition 1

Figure 3 illustrates simulation of condition 1 in this model. Condition 1 illustrates the simulation of conditions when 90% of the people applied health protocols but the government did not take policies related to COVID-19 control. The result was in 58 ticks or 58 days, there were 336 positive cases.

Condition 1 as happened in the case in DKI Jakarta, the capital city of Indonesia, during the period where Large-Scale Social Restrictions (PSBB) were not implemented. In this condition, almost all people apply health protocols such as wearing masks properly, washing hands, and keeping their distance, however, access to various places has been opened by the government, such as tourist attractions, malls, electric trains, and Jakarta's free entry and exit. In this condition, the addition of active cases in Jakarta is very high, as 7,157 additional positive cases in July 2020, 8,569 in August, and 11,245 in September 2020 (Christy, 2020). From this significant addition of cases, the Governor of DKI Jakarta has re-implemented large-scale social restrictions. in Jakarta.

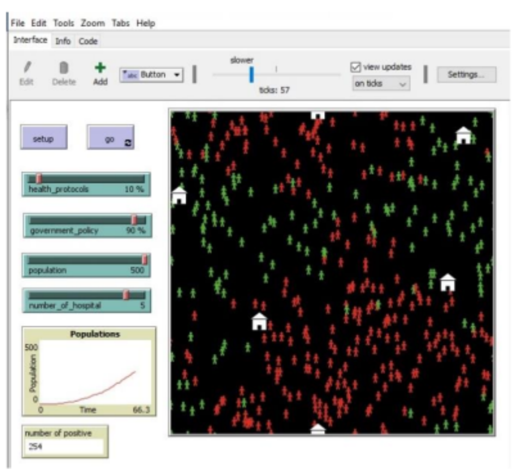

Figure 4. Simulation of condition 2

Figure 4 illustrates the condition 2. The condition 2 is a simulation when a few people apply health protocols but the government provides many policies related to COVID-19. In this condition, after the experiment for 57 ticks or 57 days, there were 254 positive cases.

Condition 2 is a condition when people do not believe in COVID-19, or people have forgotten about this virus and are getting bored of implementing health protocols. In this condition, even though the government enforces policies related to COVID-19 such as limiting activities, if the community does not apply health protocols, the addition of cases will also occur quickly.

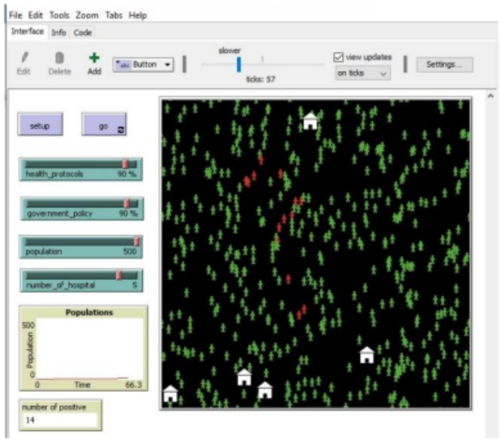

Figure 5. Simulation of condition 3

Figure 5 illustrates simulation of condition 3 in this model. The condition 3 describes when 90% of the people implement health protocols well and the government supports them with policies on limiting public facilities and areas. The results showed that after 57 ticks or 57 days, only 14 positive cases occurred. This is very different from conditions 1 and 2.

Condition 3 is a condition that is expected to occur because even though there are still additional cases, the increase in these cases can happen very slowly. This is much slower than condition 2 and condition 3. However, it may be challenging to implement this condition because society and the government also need the economy to keep running to prevent hunger, poverty and crime.

Although the government, in this case, government policy, cannot fully lock down its territory. The government can consider various other restrictions that have an impact to reduce the rate of spread of COVID-19. Government policies, in this case, include limiting events that involve many people gathering, sweeping to various crowded places and not implementing health protocols, sanctions against offenders, etc.

6. Conclusion

From the research that has been done, it can be seen that modeling the spread of COVID-19 can be done by using Agent-Based Modeling. Models made with Agent-Based Modeling can be adapted to existing conditions. From this study it can be seen that the implementation of health protocols influences the spread of COVID-19. Likewise with the existence of policies from the government, this also has an influence on the spread of COVID-19. The more people who apply health protocols, the slower COVID-19 will spread. The more restricted public access by government policies also made the spread of COVID-19 slower. The implementation of health protocols needs to be carried out along with the existence of government policies to control the spread of COVID-19. Further research is needed to see the effects of various things in more detail such as closing schools, places of worship, public transportation, and various other things that are more specific. Further research can also be carried out for various cities in Indonesia that have different characteristics.

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