Simulation and Visualization of Bus Operation with Passengers using Actual Bus Management Information

Takehiro ARAI[1], Kei HIROI[2], and Nobuo KAWAGUCHI[3]

[1] Graduate School of Engineering, Nagoya University, Aichi, Japan
arai@ucl.nuee.nagoya-u.ac.jp
[2] Institutes of Innovation for Future Society, Nagoya University, Aichi, Japan
k.hiroi@ucl.nuee.nagoya-u.ac.jp
[3] Graduate School of Engineering, Nagoya University, Aichi, Japan
kawaguti@nagoya-u.jp

Abstract. Buses are an important transportation means for commuting, schooling and elderly people, but there are many delays and there is a problem that it tends to be crowded at commuting time. Changing the operation schedule may alleviate these tasks, but the optimal change is not clear, and trial and error is required. As the number of changes in the diversity increases, it becomes necessary to notify the user many times, which is a heavy burden for both users and bus operators. Therefore, in this research, we model the appearance of passengers at bus stops using bus driving data and build an environment simulating various driving situations. At that time, from the waiting time of the bus and the congestion rate, " pass dissatisfaction degree " is defined. By doing this, we measure the degree of dissatisfaction when the driving situation changes and quantitatively evaluate it. In addition, we will visualize the driving situation and aim for proposal of operation method considering both improvement of convenience for users and efficiency of bus operators.

Keywords: Bus, Simulation, Visualization, Big Data

1 Introduction

Buses are an important transportation means for commuting, schooling and elderly people, but there are many delays and there is a problem that it tends to be crowded at commuting time. Changing the operation schedule may alleviate these tasks, but the optimal change is not clear, and trial and error is required. As the number of changes in the diversity increases, it becomes necessary to notify the user many times, which is a heavy burden for both users and operators. Therefore, in this research, we will consider using this simulation using bus actual data to alleviate this congestion, delay and wasteful traveling. At this time, we defines " dissatisfaction degree " which indicates how each passengers dissatisfy the buses get on regardless of awareness. The degree of dissatisfaction is considered to change depending on various factors such as season, time zone, area, etc., so the value criteria will change by each passenger. Following this, we will consider operating that improves efficiency while improving this degree of dissatisfaction. Furthermore, we built a tool that confirms how the operation changes by the condition of simulation such as the number of bus or passengers.

2 Related research and issues

2.1 Related research

Many researches have been done as a solution to the optimization problem for research to improve the operation of the bus. Method of formulating it as a combinatorial optimization problem with constraints on the number of operable buses and required time, such as [**?**], which decides from the road network on which the bus runs, by partial optimization problem, etc. [**?**] . Studies have also been made to reproduce the operation of buses using computer simulation. [**?**] calculates the influence in the case of executing the priority measures of the bus by considering the micro traffic condition, by simulation. In addition, researches on demand bus, which observes the demand of passengers in real time and determines travel each time, has been actively conducted by a method combined with simulation. [**?**] compares the convenience of the demand bus and fixed route bus by simulation, and seeks optimal operation of each using the method of genetic algorithm and auction of multi agent. In [**?**], demonstration experiments are carried out by setting the real-time operation route of the demand bus by simulation, and it shows effectiveness. Even in [**?**] and [**?**], we perform our own demand bus routing simulation, and [**?**] performs social experiments with it. In the research on the demand bus, attempts have been made to optimally operate using optimization problems and simulation, which is [**?**,**?**].

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2.2 isuues

In the above research, we propose optimization demand bus aiming at eliminating congestion and delay of bus operation, but appropriate optimization by user's request is not done. For example, in commuting and school time zones, it is predicted that many people think that they want to arrive at the destination as soon as possible even if some congestion is permitted, and those who come home from the shopping mall may take some time It is expected to think that you want to sit and move as possible. Therefore, in this research, in addition to improving the efficiency of operation on the bus operator's eyes, we also consider the optimization by adding the user's eyes. Taking into account the changing season, time zone, and region that users require for bus operations, we propose and consider a system that will optimally operate buses at each point in time.

3 Proposed system

3.1 Simulation outline

In consideration of the problem of the previous chapter, we first define " dissatisfaction degree " which indexes the difference between the user's requested operation and current situation. We simulate various driving situations by simulation and consider operation that reduces dissatisfaction degree while improving operation efficiency.

3.2 Definition of dissatisfaction degree

The degree of dissatisfaction is thought to vary depending on various factors such as season, time zone, region, etc. In this research, as the evaluation item to measure dissatisfaction degree, we define three indexes: the time from arrival at the bus stop to ride T_{wait}, the delay time from getting on to getting off T_{delay}, Define the interval I, the congestion rate C during boarding. The weights for these evaluation items change according to season, time zone, area, etc., thereby the dissatisfaction degree is determined as a whole. In this research, it is decided that the dissatisfaction degree as a whole is determined by the linear combination of the evaluation item and the weight composed of the factor. That is, each evaluation item is multiplied by the weight ω_i, and the dissatisfaction degree S in the whole is the sum of the weighted evaluation items. Each weight varies depending on factors such as season, time zone, area, etc. Representing this in an expression

$$S = \omega_1 T_{wait} + \omega_2 T_{delay} + \omega_3 C \tag{1}$$

3.3 Simulation design

in this section, we show how simulation is performed with data / configuration. In this research, we use three kinds of data for simulation, bus driving data, passengers appearance rate, and data on passenger's destination. These are data extracted and calculated based on bus operation data provided from Meitetsucom Co., Ltd.. In the simulation, three types of bus stops, buses, and people are defined, and these are interacted and simulated. First the outline of the data received and for simulation is shown, and next the motion of each element at the time of simulation is shown.

Data used for simulation The data to be used is bus operation data provided by Meitetsucom Co., Ltd.. Among the range of the Meitetsu bus service, we use the one in Okazaki city, Aichi prefecture, Japan. There are two types of data are used: bus departure data and data on passengers getting on and off. Bus departure data is classified by the bus operation for each date / time / route (operation area) / system / up or down / first departure time. It is recorded what

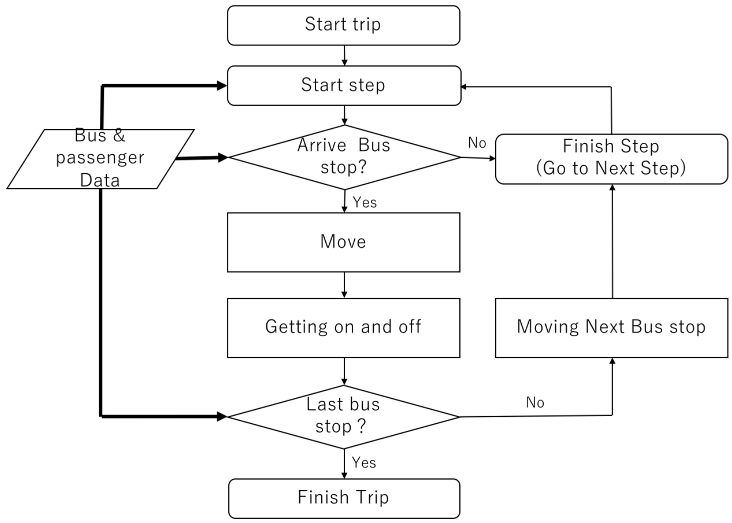

Fig. 1. Behavior of bus during simulation

time each bus depart predetermined and in fact. Data on passengers getting on and off is recorded when passengers use the bus, at what time and from which stops they get off at which stop. Currently, we reproduced the operation on July 8, 2016 where the number of passengers was the largest between July 1 and 16, 2016.

Behavior of bus stops The stops hold separate numbers that identify the respective stops. This number is used to judge which bus stop the bus should head to. In addition, each stop point holds the passenger appearance rate for each bus stop / hour calculated from data as a series of constants.

Behavior of bus A flow chart is shown in Fig. **??**. Each bus moves to a bus stop at the time of departure of each bus stop, take on board passengers waiting there, take down passengers whose destination matches each bus stop. Since it is the time of moving other than the time of departure, always move to a place that does not suffer from stops. And at the next time of departure, it will move to a stop again and take on board and take down of passengers. In order to measure congestion rate, record the number of own boarding during each movement.

Behavior of human A flow chart is shown in Fig. 2. People appear by the probability of appearance at each bus stop. As an example, one step of the simulation is set to 1 second. Then, for each step of the simulation, a random number that returns the number of occurrences per second (that is, the x axis of

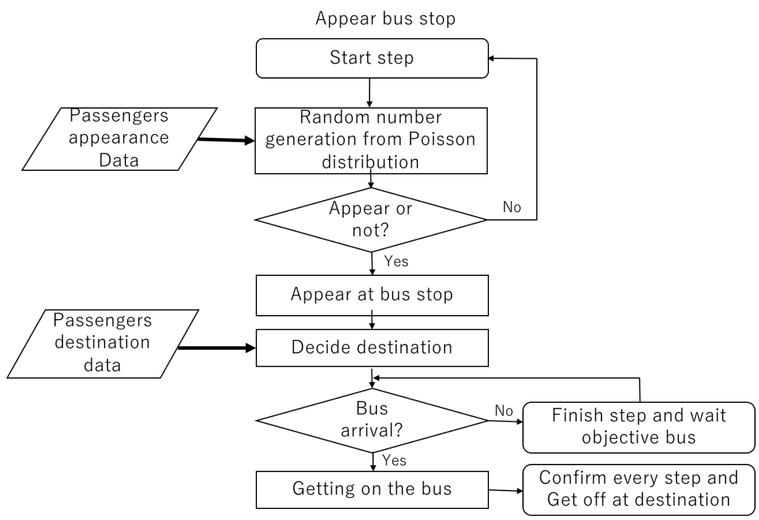

Fig. 2. Behavior of human during simulation

the Poisson distribution) is acquired according to the Poisson distribution with the appearance probability every second. Since the appearance rate per second is small, almost all of the random numbers according to the Poisson distribution are 0 or 1. When this becomes 1, a person appears at the corresponding bus stop. When the bus arrives at the bus stop, it is judged whether or not his destination exists at the destination of the bus, and if it exists, it gets on. When it arrives at the destination stop, get off. At this time, the own riding time is recorded.

3.4 Visualization design

For visualization, deck.gl is used. This is a WebGL-based big data visualization framework developed and published by Uber. It can analyze and draw on GPU basis and visualized data can be combined in multiple layers. Here, we visualize simulation results of bus operation based on each data. The bus operation visualization library that we are developing in this research is called BusDataVisualizer.

4 Implementation

The system actually implemented in this research is shown in the figure 3, and its contents are shown below.

4.1 Formulation of simulation data

First, data provided from Meitetsucom Co., Ltd. is formatted as data used for simulation. This is done by programming with Python. In this research, since

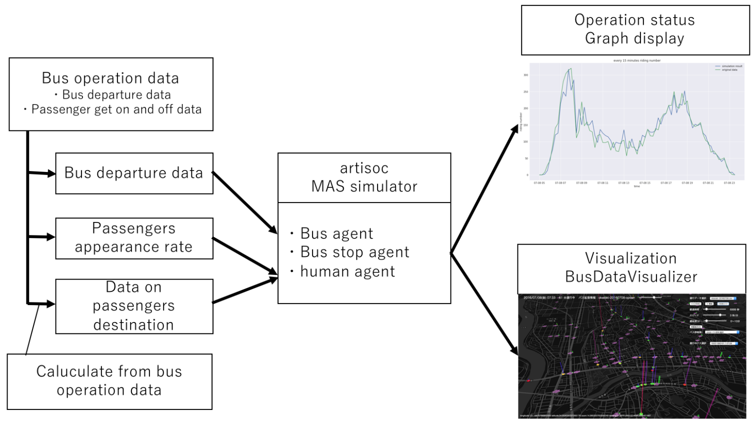

Fig. 3. Diagram of simulation

MAS (multi agent simulation, hereinafter MAS) artisoc is used as a simulator, data is created in consideration of operating each agent. Three types of data are used: bus departure data, data on passengers appearance rate, and passenger's destination data. Details are as follows.

Bus departure data By using bus departure data, data describing the bus stop timing of the bus agent in the simulation is created. At the time of simulation, the bus agent determines the operation with reference to this data.

Data on passengers appearance rate Data on the passengers appearance rate is data describing the proportion of passengers appearing at each bus stop and time. This is a value calculated from data on getting on and off of passengers. Collect the boarding data for each boarding stop, and further summarize data for every 15 minutes. Then calculate the number of passengers every 15 minutes and calculate the rate of appearance per minute by dividing it by 15. Then let this be the occupant appearance rate every 15 minutes.

Data on passenger's destination The data on the passenger's destination is the probability that the passengers who appeared at the bus got off at which stop. Data on passengers getting on and off are gathered for each bus stop and from which station they headed to the bus stop is calculated as a ratio. For example, if two people, three people, four people go to three places from stop 1 to stops A, B, C respectively, then the probability of each bus stop becomes $\frac{2}{2+3+4} \approx 0.22$ to A, $\frac{3}{2+3+4} \approx 0.33$ to B, $\frac{4}{2+3+4} \approx 0.44$ to C, respectively. The proportion of the destination may change depending on the time zone, but currently this time information is not considered.

4.2 Simulation

Next, the simulator used in this research and the behavior of each agent in the simulation are shown.

Used simulator In this research, artisoc (URL: http://mas.kke.co.jp/), MAS developed by KOZO KEIKAKU ENGINEERING, was used as a simulator to reproduce the operation of the bus. The MAS is an agent based simulation that places an agent representing each object in the defined space and the agent takes action by hijacking behaviors determined for each step. In this research, we define three kinds of agents: “stop agent”, “bus agent”, “human agent”. These agents perform predetermined operations for each step. In this study one step = 1 second is treated.

In this research, the results of simulation are visualized by BusDataVisualizer. Therefore, as a result of the simulation, only information on how many passengers got on and off at the time of each bus and which stop point is needed. Therefore, instead of reproducing the road condition and the route on the map at simulation, the bus stop agents randomly arrange so that they do not cooperate with each other, and the bus agent instantaneously moves to a bus stop and takes on and off when departure time comes. The operation of each agent is shown below.

Behavior of bus stop agent Each stop agent judges whether or not to cause a passenger to appear every step based on the data on passengers appearance rate. This judgment is based on a function that returns a random number of according to the Poisson distribution which is a default function in artisoc. Since 1 step = 1 second in this study, the value calculated as the passenger appearance rate [people / minute] is further divided by 60 and the value is taken as the appearance rate per second as argument of this function. Since the value of the argument is very small, it is assumed that only 0 or 1 is obtained as a return value, and when the return value becomes 1, a passenger appears. Furthermore, from data on passengers destination, the destination of the emerging passenger is determined.

Behavior of bus agent Each bus agent moves to a bus stop at the time of departure of each bus stop, takes on passengers waiting there, and takes off passengers whose destination matches each bus stop. Since it is moving time other than the time of departure, always move to a place that does not suffer from stops. And at the next time of departure, it will move to a stop again and take on and off of passengers.

Behavior of human agent Each human agent appears in the same coordinates as the bus agent. When the bus arrives at the bus stop, it is judged whether or not his destination exists at the destination of the bus, and if it exists, it gets on. When it arrives at the destination stop, get off and delete itself.

Derivation of dissatisfaction degree In this research, there is no study on how delay time and congestion rate, which is an indicator for deriving dissatisfaction degree, change with time / place. This will be a subject for the future.

4.3 Graph display of simulation results

Based on the results of the simulation, a graph of the number of passengers over time is displayed, and the actual operation data and the simulation result are compared. As a comparative example, illustrate Fig. 5 and Fig. 6. Details about this are given in the next section.

4.4 Visualization

Next, an implementation in visualization will be described. As described above, the simulation result is information on the number of passengers getting on and off at what time and at each bus stop of each bus. Visualization was carried out based on this information.

Data form The simulation result is data on how many passengers each passengers get on and off at each bus stop. This is formatted as the json file format used by BusDataVisualizer.

Visualization form Figure. **??** shows the specifications of the current BusDataVisualizer. In this figure, light purple circles represent buses, green, yellow and red circles represent buses. The difference in color represents the degree of delay in the bus. Changes in color due to delay fractions are shown next to figure **??**. At this time, it becomes variable on the display screen how many minutes the color becomes red. Also, by displaying a vertical bar at each bus / bus stop, the bus shows the number of passengers at that time, and the bus stop indicates the number of people waiting for getting on at that time. Four vertical bars can be displayed for each bus and bus stop, and different data can be allocated to each.

5 Simulation result

The results of the simulation using artisoc are shown. Simulation results can be expressed in two types of forms: the transition of the number of passengers to time and the transition of the number of passengers waiting for boarding at a bus stop to time.

5.1 The transition of the number of passengers to time

The transition of the number of passengers with respect to time is shown in the figure 5. The horizontal axis represents time and the vertical axis represents the

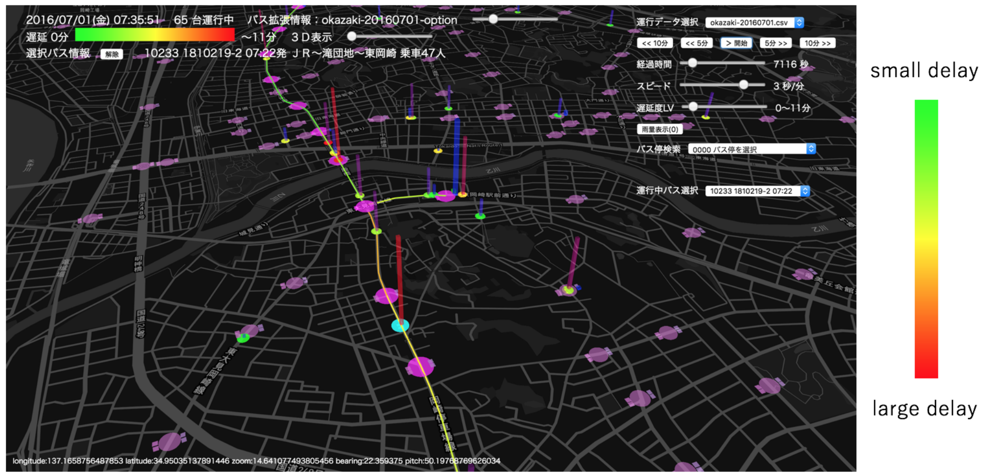

Fig. 4. The image of BusDataVisualizer and color display

number of passengers, which shows the number of people who got on every arrival of the bus at all stops. Also, if you represent a ride every time, the granularity is too fine to lack visibility, so it is summarized in the number of passengers every 15 minutes. In this way, it can be seen that the number of passengers is close to actual data. The correlation coefficient between the actual data and the simulation result was 0.94. Next, at a certain bus stop, the graph showing the transition of the number of passengers to time is shown in the figure 6. It can be seen that even in the case of a bus stop, similar to the whole, the transition of the number of passengers can be reproduced.

5.2 The transition of the number of people waiting for boarding at a bus stop to time

The transition of the number of passengers waiting for boarding at each bus stop is shown in the Fig. 7. It can be seen that people concentrate on commuting time, drawing a gentle curve in the afternoon and various people riding. It seems that some degree of reproducibility is obtained. An examination of the degree of reproducibility of this is a future development. In addition, this data is the result of excluding changes in stops “Higashi Okazaki” and “Okazaki”. Adding these stops did not result in accurate results. These stops are the main stops in Okazaki city, and people with various destinations gather. Since the probability of the destination of the passenger runs through the day, there is a possibility that the passenger appears even though there is no bus scheduled to head towards the destination.

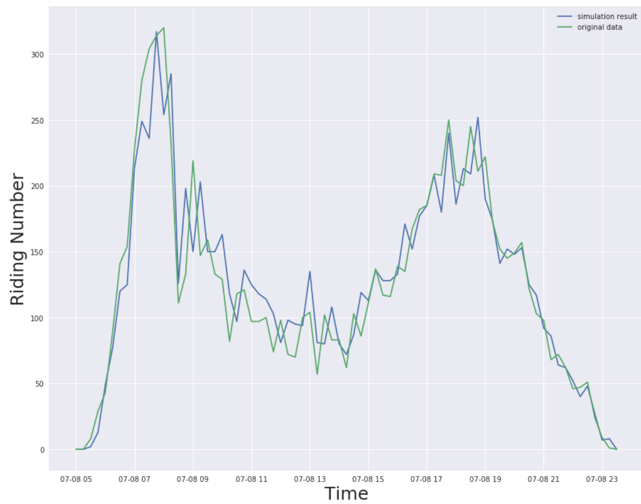

Fig. 5. Changes in number of passengers to time at all stops

6 Current status and issues of visualization

The purpose of visualizing the simulation is to visually confirm how the passenger flow changes when changing simulation conditions. The simulation conditions are the bus operation time, number of operations, and occupant appearance rate. We will make various changes so that various driving situations (such as days of the week and seasons) are reproduced and the defined dissatisfaction degree is improved.

In the present situation, as shown in Fig. **??**, circles representing buses and bus stops, bars representing the number of passengers and waiting people are shown on the map. Currently, only one bar representing the number of passengers on the bus is used, and bars representing the number of people waiting for a bus at the bus stop are divided up and down and two are used.

As a problem in this specification, it is difficult to know which simulation result each bus is displaying, when changing the number of bus operations. In addition, changes in the flow of passengers as a whole are becoming hard to understand at present. In order to further improve the visibility, it is necessary to further refine the design.

7 Conclusion / future development

In this research, when optimizing bus operations by simulation, we adopted the concept of "dissatisfaction degree" which is an index that changes the evaluation criteria of operation for each user. By doing this, we aim not only to improve the

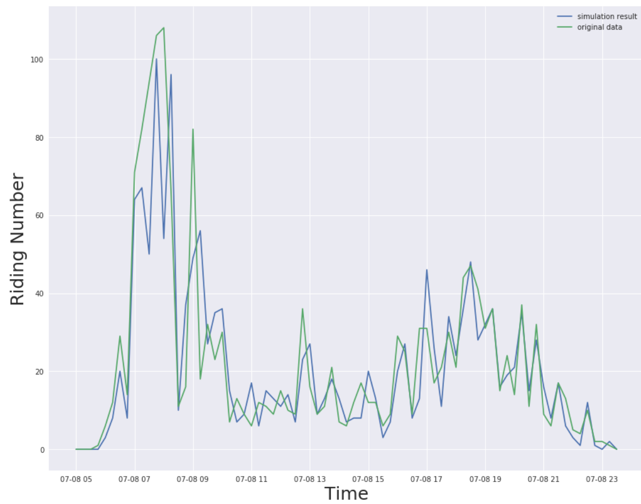

Fig. 6. Change in number of passengers to time at "Okazaki station front"

efficiency of operation on the bus operator's point of view, but also to a comfortable bus operation with each user's perspective. Using actual transmission data provided by Meitetsucom Co., Ltd., we constructed a simulation to reproduce bus operation using MAS artisoc. We confirmed that the simulation was done correctly by approximating the number of passengers per hour to the correlation coefficient of 0.94 between simulation and actual operation data. In addition, a visualization library that displays the number of people waiting for boarding and number of passengers on the map on each stop and bus at each bus stop and bus is made available by the visualization library BusDataVisualizer using deck.gl.

As a future development, a clear definition of dissatisfaction level can be cited first. It is necessary to examine the correlation between the state such as the area / time and the operation time / congestion rate, and the influence of the operation time / congestion rate on the overall dissatisfaction degree. Next, it is necessary to calculate the probability with respect to the destination of the passenger divided by time, to make it a more accurate probability, and then to examine how much the number of people waiting for boarding in time is actually reproduced. Also, in the current simulation, the behavior of the bus is completely determined by time, and it is not a model that delays during simulation. Therefore, it is necessary to solve this point. Then, we examine the influence on unsatisfactory degree when changing the operation schedule variously. [1] [2]

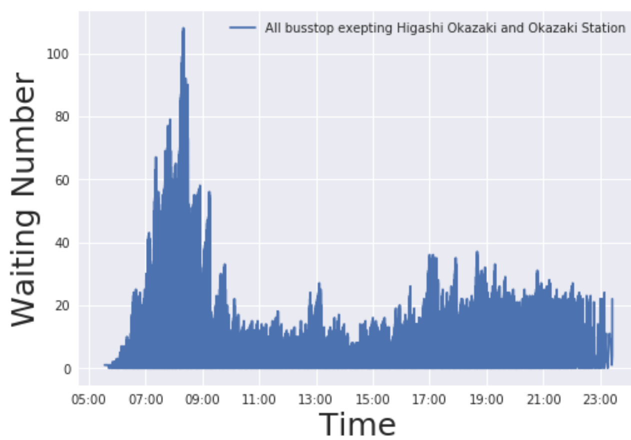

Fig. 7. Changes in the number of people waiting for a ride against time excepting “ Higashi Okazaki ” 、“ Okazaki Station ”

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