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SIMULATION IN CONTAINER TO REDUCE WASTED SPACE WITH FIRST FIT DECREASING AND LARGEST AREA FIRST FIT METHODS

Theodorus Jonathan Nugraha [1] & Friska Natalia [2]

[1] Department of Information System, Multimedia Nusantara University, Banten, Tangerang, Indonesia

[2] Lecturer, Department of Information System, Multimedia Nusantara University, Banten, Tangerang, Indonesia

ABSTRACT

Delivery of goods using large containers requires a large cost. One way that can be done to reduce the cost is to fill the container as much as possible so the numbers of containers needed for a delivery can be reduced as well as the cost needed. This study will describe a way to optimize the use of space in a container with three different shapes of items such as a box, cylinder, and sphere, then build a 3D simulation in the arrangement of items in containers with two different sizes which are 20 feet and 40 feet container. The results of this study will be presented in the form of a 3D simulation built using the PHP language and use two methods of packaging goods such as first fit decreasing and largest area first-fit. FFD algorithm will be used in determining the order of items that will fit into a container with a sort by the largest size. LAFF algorithm will be used in arranging the item's position in the container.

KEYWORDS: *Three-Dimensional Simulation, Largest Area First-Fit, First Fit Decreasing*

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INTRODUCTION

Good space utilization will reduce the number of containers needed for delivery as well as reduce the costs needed. In order to utilize the space, a solution should be found in managing goods. One solution is to use a simulated arrangement of items. According to [2], simulation is a good tool to perform experiments in order to find the best possibilities. By using simulation, in a short time can be determined the right decision and at a cost that is not too big because everything is done by computer. Simulations will facilitate users in making the arrangement of items, and find the right decision in a short time. In order to assist the process of packaging, has been made a simulation of packing goods [4]. In that study, used an algorithm packing of goods, namely largest area first-fit (LAFF) and developed a simulation of the arrangement of items. However, the simulation has three shortcomings which are only the shape of 2D simulation displayed (length and width) and can only use one form of goods (cube) and one container size only (20 feet).

There are 3 similar studies that have been developed previously: The first study, the first fit decreasing algorithm will pack every item present into the container by sorting it in decreasing based on their size or in other words sorting the items based on the largest to the smallest size. After sorting those items, this algorithm will pack each item into an existing container same as the first fit algorithm which to pack goods into the first container and will open a new container if the item can't be packed into an existing container. This research can conclude how first fit decreasing algorithm work [1]. The algorithm will pack goods based on the largest size without considering other aspects into the container available. It will continue to repeat in each container where each item will be packed in the first container, second container, and so on until a suitable container is found and will repeat it for the next item. There is a major disadvantage of this algorithm which requires resources to perform the looping process because this algorithm will continue to check all existing containers. If a lot of containers used, the packaging process will be longer. However, there are also advantages of this algorithm that the packing process does not require much calculation or operation where it is only necessary to calculate the size of each item and pack it directly into the container [5,6]. The second research use as a reference is described a new algorithm called Largest Area First-Fit (LAFF). This algorithm will pack goods which have the largest surface area into the container first. If there are two items with the similar surface area were found, this algorithm will check the height of the two items where the goods that have a lower height will be packed first. After packing the goods with the largest surface area, this algorithm will check whether there is still free space around the goods and goods which fit in the empty space. If it does not exist, this algorithm will place the item above the highest item that has entered and so on until the container is full. This research can conclude how the LAFF algorithm works. According to the researchers, the LAFF algorithm has advantages which the algorithm prioritizes efficiency in the use of containers. The LAFF algorithm will pack the goods into a container by prioritizing the goods that have the lowest height first but have the largest width. However, there is a weakness of the LAFF algorithm when this algorithm packs the object and the bottom level is full, then this algorithm will create a new level based on the highest height of the objects inside. This will cause empty space wasted inside the container. Moreover, if the algorithm finds the largest wider item, it will directly pack it into the container without comparing the height of the object, then the available empty space can be larger[3,7].

Based on another deficiency of the LAFF algorithm is that in previous studies, researchers only use a form of boxes, while in this research will use different shapes. In this research use two methods in packing goods into the container: LAFF and FFD. In this research will make an improvement in the simulation to develop features that will show a form of 3D (length, width, and height), can choose the form of the goods to be packaged (cubes or blocks, cylinders, and spheres) and optimizing the algorithm in the placement of goods. In addition, simulations are made to be able to choose the size of the containers (20 ft and 40 ft). The algorithm in goods arrangement will be made by combining the two methods of packaging that are First Fit Decreasing (FFD) and LAFF. FFD algorithm used in this study to consider the height of goods that were previously in the algorithm LAFF not considered and LAFF algorithm used to determine the position of goods. By combining these two methods, it is expected that empty space in the container can be minimized and find the optimal solution. A simulation will be built in the form of a prototype website.

PROBLEM DEFINITION AND PROBLEM SOLVING METHODS

Problem Definition

Based on observations that researchers have done, researchers found some shortcomings in the website bungkus.ml where researchers will improve and improve the quality of the website. Here are the shortcomings that exist on the bungkus.ml website:

- The use of LAFF methods that still have shortcomings in the arrangement of goods.
- The size of the container used is only one size ie 20- foot containers.
- The form of goods that can be put into the container is only one form of the cube/beam.

- The simulation results are only shown in 2D form (length and width).

Therefore, researchers will correct the shortcomings of the bungkus.ml website by doing this research. Website simulations that will be researchers will have some advantages compared to www.bungkus.ml. The advantages are as follows:

- Using two algorithms FFD to determine the order of goods entered and LAFF to determine the position of goods inside the container.
- The size of the container will be added to two kinds of 20 and 40 feet where the user can choose between the two sizes.
- The form of goods that can be put into containers will be added into three forms: tubes, balls, and cubes/blocks.
- The simulation results will be displayed in 3D (can be seen in length, width, and height).

There are two independent variables in this study: The form of goods consisting of three kinds, namely cube or beam, tube, and ball; The size of the items that the user can fill. While the dependent variable in this study is the size of the container that can only be selected by the user and cannot be changed. In this research will analyze the data by looking at the results of the observations made on previous research and comparing it with the results of this study. This research will use two algorithms that are FFD to determine the order of goods entering and LAFF to determine the position of goods in a container.

There are two scenarios in this study: Goods with the same shapes and Goods with the different shapes. The calculation of goods with the same shapes is not really different with the different shapes. However, the second case is more complex. Therefore, in this paper will show the calculation packing goods into containers of different shapes. In this case, we will use a combination of both algorithmic methods that researchers have explained earlier with their usefulness. Here is a packing step:

- The form of goods to be packed is a cube or beams and balls.
- Size of goods to be packed:
  - Cube (length x width x height) shows in Figure 1- 5:

A = 1 cm x 1 cm x 1 cm

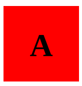

Figure 1: Goods A Case Example 2

B = 1 cm x 1 cm x 1 cm

Figure 2: Item B Case Example 2

C = 1 cm x 2 cm x 1 cm

Figure 3: Item C Case Example 2

D = 1 cm x 1 cm x 2 cm

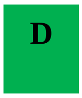

Figure 4: Item D Case Example 2

E = 1 cm x 2 cm x 2 cm

Figure 5: Goods E Case Example 2

- Ball (radius) shows in Figure 6 and 7:

  F = 1 cm

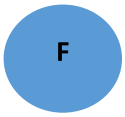

Figure 6: Goods F Case Example 2

G = 2 cm

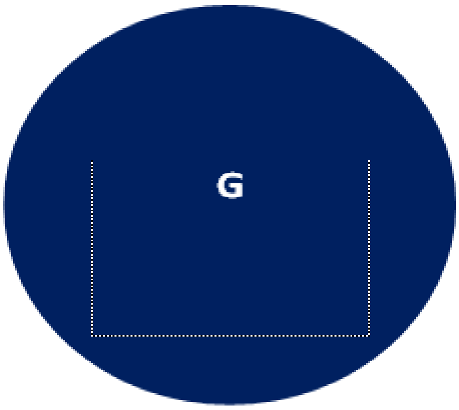

Figure 7: Goods G Case Example 2

- Size of the container to be used (length x width x height) shows in Figure 8 and 9:

  Size 20 = 5 cm x 2 cm x 2 cm

Figure 8: Container 20 Case Example 2

Size 40 = 12 cm x 2 cm x 2 cm

Figure 9: Container 40 Case Example 2

Determination of Packing Sequence with FFD Algorithm

All items will be compared in size to determine the largest size of the goods. The way that researchers will use is to calculate the breadth and height of goods to get the greatest value. Please note for a shape other than a cube or beam, then the calculation will be done by taking the largest size of the wake of the space. For example, for the ball, then the formula becomes diameter x diameter. The following is the result of the calculation of the base area multiplied by the height of each item:

- A = 1 cm3
- B = 1 cm3
- C = 2 cm3
- D = 2 cm3
- E = 4 cm3
- F = 4 cm3
- G = 16 cm3

Based on the computations that have been compared, the goods will be packaged in the order of G, F, E, C, D, B, and A. However, goods G cannot be packed into containers because the width and height of the container is only 2cm while the diameter of the goods G is 4 cm. Therefore, the packing order of goods will start from the goods F.

Determination of Packaging Position with LAFF Algorithm

Based on the sequence of items already obtained using the FFD algorithm, the LAFF algorithm will arrange the position of the goods inside the container to be produced with a 3D view. In addition to overcoming the visualization of FFD, the researchers also proposed a way to minimize the shortcomings of the LAFF algorithm by filling the items with the largest size first in accordance with the FFD algorithm, both at width and height in order to maximize the available space. Based on the sequence of items obtained from the FFD algorithm and positioning of the LAFF algorithm, Figure 10 is the result of the packing of the goods.

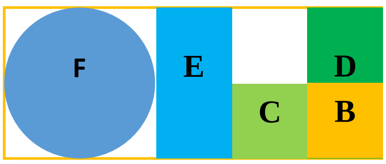

Figure 10: Combined Simulation Results LAFF and FFD Container Size 20

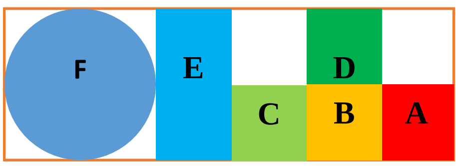

Figure 11: Combined Simulation Results LAFF and FFD Container Size 40

Figure 10 shows the simulation result after incorporating the FFD and LAFF method on a 20 sized container where item A cannot be inserted because the second level of goods is considered to be from the high F. In Figure 11 describes the simulation result after combining the FFD and LAFF methods on the 40 size container where all the goods can be included because the lowest level still has space. It should be noted that the width of the item has been taken into account in the image, but is not visible due to media limitations. Items B and D are located side by side where item D is at the back of item B.

Calculate the Volume of Goods and Containers

After packing the goods into the container, the next step is to calculate the used or volume used and the volume of wasted or unused volume. How to calculate the volume used is to add all the volume of goods that have been packed into the container. How to calculate wasted volume is by subtracting the volume of the container and volume used. Here's the step how to calculate it.

Container Size 20:

Volume used (goods already packaged):

F = (4/3 x 3.14 x 1 x 1 x 1) = 4.18 cm3

E = (1 cm x 2 cm x 2 cm) = 4 cm3

C = (1 cm x 2 cm x 1 cm) = 2 cm3

D = (1 cm x 1 cm x 2 cm) = 2 cm3

B = (1 cm x 1 cm x 1 cm) = 1 cm3

Total volume used = 13.18 cm3

Container volume = 5 cm x 2 cm x 2 cm = 20 cm3

Volume wasted = Volume of container - Volume used

= 20 cm3 - 13.18 cm3

= 6.82 cm3

Container Size 40:

Volume used (goods already packaged):

F = (4/3 x 3.14 x 1 x 1 x 1) = 4.18 cm3

E = (1 cm x 2 cm x 2 cm) = 4 cm3

C = (1 cm x 2 cm x 1 cm) = 2 cm3

D = (1 cm x 1 cm x 2 cm) = 2 cm3

B = (1 cm x 1 cm x 1 cm) = 1 cm3

A = (1 cm x 1 cm x 1 cm) = 1 cm3

Total volume used = 14.18 cm3

Container volume = 12 cm x 2 cm x 2 cm = 48 cm3

Volume wasted = Volume of container - Volume used

= 48 cm3 - 14.18 cm3

= 33.82 cm3

Problem Solving Method

In this study, the combination between LAFF and FFD algorithms is used. FFD algorithm will be used in determining the order of goods. While the LAFF algorithm will be used to determine the position of goods. In this research will also create a simulation which will have some advantages compared to the previous study. This simulation will be 3D-shaped with three kinds of items that can be selected, i.e. cylinder, sphere, and box. In addition, in this simulation users can choose between two container sizes, which are 20 feet and 40 feet. Figure 12 describes the workflow of the FFD and LAFF algorithms in this study. The first step is this method will check the shape of the items. If the shape of the item is a cube, the surface area is obtained by multiplying the length and width. Meanwhile, if the shape of the item is a cylinder, the surface area is obtained by multiplying the diameter and length. Meanwhile, if the shape of the item is a sphere, the surface area is obtained by multiplying the diameter and diameter. After multiplying the surface area, the result will be saved. Then, it will check whether the surface area of the item being examined (item x) is greater than the surface area of the selected item. The selected item is random at first. If so, the surface area of item x will be changed to the width of the selected item surface area. If not, the surface area of item x will then be checked if it is the same as the surface area of the selected item, if yes then it will check again, whether the height of item x is higher than the height of the selected item. If yes, item x will be the selected item. If not, then the selected item will not change as a comparison with other item. After that, it will be checked whether there are any items available, if there aren't any it will end, but if it still available, will be checked the size of the items again from the beginning and the order of items may change according to the surface area and the height of the items.

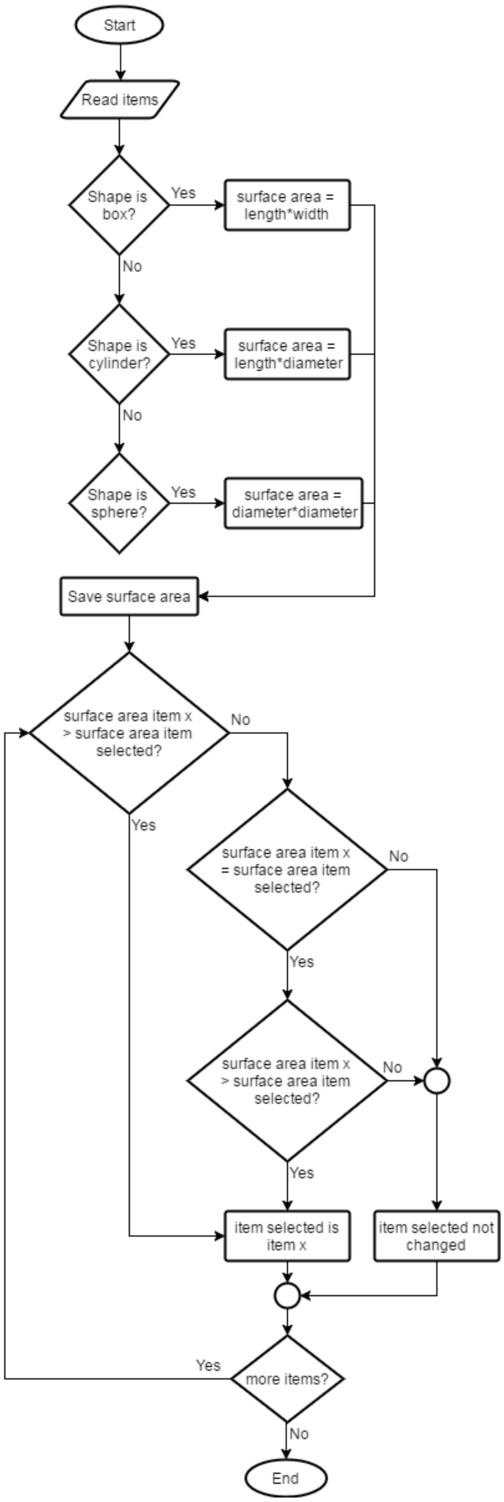

Figure 12: Flowchart of FFD and LAFF Methods

ANALYSIS AND RESULTS

The first problem to be solved is to consider the height of goods to determine the order in the packing goods. In order to solve the problem will use two methods ,namely FFD and LAFF. Here is the explanation.

First Fit Decreasing Method

First Fit Decreasing (FFD) method will be used in this study to determine the sequence in packing the goods into the container, that is by comparing all the available goods then determine the sequence of goods which will be packed into the container.

Largest Area First-Fit Method

The Largest Area First-Fit (LAFF) method will be used in this study to determine the position in packing the goods into the container, that is determining where the goods will be placed inside the container.

Development of 2D to 3D Simulation

The previously designed simulation has a 2-dimensional visualization. Simulation in 2 dimensions can't display all side of goods, but only from above only and level of goods can't be seen. Therefore, this study will develop the visualization into 3 dimensions. 3-dimensional simulation can display all sides of the goods, both length, width, and height and level of goods can be seen clearly.

In Developing 3-Dimensional Visualization, Here are the Steps:

- The combination between first fit decreasing (FFD) method to determine the packing sequence of goods and largest area first-fit (LAFF) method to determine the position of the goods inside the container. This is necessary for the packaging of goods to be more optimal. FFD method will determine the order of goods based on the largest size, but FFD method can't determine the position of goods because it is only suitable for 2-dimensional packing problem. LAFF method will determine the position of goods into containers because this method is suitable for 3-dimensional packing and will pack the goods starting from the bottom left container first.
- In this research use the Three.js library to create 3-dimensional objects into the simulation website for visualization to be 3-dimensional.

Addition of Item Shape

In previous studies, the form of goods that can be used is the only box. While in this study, the form of goods that can be used is the cylinder, sphere, and a box. The addition of this form of goods serves to make the simulation more varied and more in line with the original goods. Increasing the form of goods requires different calculations from previous studies. In the previous studies, the calculation of surface area was done by calculating the length multiplied by the width of the box. While in this study, the calculation is different for each shape as seen in Fig 3.1.

Addition of Container Size

In the previous study, the container size available is 20 feet. While in this study added a 40 feet container size to fit the actual container standard size. Therefore, there are two container sizes of 20 and 40 feet.

Testing

Testing the simulation designed for 50 times to compare the result that is kemasin.com with a simulation which has been designed by the previous study that is bungkus.ml. However, on bungkus.ml there are only 20 feet container sizes available and the goods shape is the only box so in this comparison, user input the goods with the same amount and size as well as the same container size. This comparison is needed to find out how much difference there is in reducing the empty space inside the container because there are different methods that used. Table 1 will show five simulation results that have done.

Table 1: Simulation Result Comparison with Previous Study

N	Goods Size (l x w x h)	bungkus.ml	kemasin.com
1	1 x 1 x 2 1 x 1 x 2 1 x 1 x 2 1 x 2 x 2 1 x 1 x 1 1 x 1 x 1 1 x 1 x 1 1 x 1 x 1 1 x 2 x 2	*Packed Items ID*: 1, 2, 4, 5, 6, 7, 8, 9 *Volume Used*: 16.00 m^3 *Volume Wasted*:14.15 m^3 *Remaining Items ID*: 3	*Packed Items ID*: 1, 2, 3, 4, 6, 7, 8, 9 *Volume Used*: 17.00 m^3 *Volume Wasted*: 13.15 m^3 *Remaining Items ID*: 5
2	2 x 2 x 2 2 x 2 x 2 2 x 2 x 1	*Packed Items ID*: 1, 3 *Volume Used*: 12.00 m^3 *Volume Wasted*: 18.15 m^3 *Remaining Items ID*: 2	*Packed Items ID*: 1, 2 *Volume Used*: 16.00 m^3 *Volume Wasted*: 14.15 m^3 *Remaining Items ID*: 3
3	1 x 2 x 1 1 x 2 x 2 1 x 2 x 2 1 x 2 x 1 2 x 2 x 1	*Packed Items ID*: 1, 2, 4, 5 *Volume Used*: 12.00 m^3 *Volume Wasted*: 18.15 m^3 *Remaining Items ID*: 3	*Packed Items ID*: 2, 3, 4, 5 *Volume Used*: 14.00 m^3 *Volume Wasted*: 16.15 m^3 *Remaining Items ID*: 1
4	2 x 2 x 1 1 x 1 x 2 2 x 2 x 2 1 x 1 x 1 1 x 1 x 1	*Packed Items ID*: 1, 3, 4, 5 *Volume Used*: 14.00 m^3 *Volume Wasted*: 16.15 m^3 *Remaining Items ID*: 2	*Packed Items ID*: 1, 2, 3, 4 *Volume Used*: 15.00 m^3 *Volume Wasted*: 15.15 m^3 *Remaining Items ID*: 5
5	2 x 2 x 2 1 x 2 x 1 1 x 2 x 2 1 x 2 x 1 1 x 2 x 2	*Packed Items ID*: 1, 2, 3, 4 *Volume Used*: 16.00 m^3 *Volume Wasted*: 14.15 m^3 *Remaining Items ID*: 5	*Packed Items ID*: 1, 3, 4, 5 *Volume Used*: 18.00 m^3 *Volume Wasted*: 12.15 m^3 *Remaining Items ID*: 2

Based on 50 test cases that have been done, can be concluded that the combination of two methods which are FFD and LAFF in this study can be stated as more optimal in reducing the empty space in the container compared with the use of LAFF method only. This can be seen from the amount of volume wasted contained in both simulations. The wasted volume in the simulation in FFD and LAFF is smaller than the previous one using only the LAFF method. Kemasin.com simulations which developed in this study has had a smaller wasted volume of 1.86 m3 compared to the bungkus.ml simulation designed in the previous study.

Evaluation of Feature Addition

The problems stated in this study can be solved and have succeeded in creating a 3D simulation because 3D visualization can already be seen and can be used properly. The addition of 20 and 40 feet container sizes and cylinder, sphere, and box shape have been tested by testing the simulation so it can be concluded that this feature is working properly.

Simulation Website

Based on the observations that have done from the previous study, can be concluded that the simulation can overcome the previous simulation shortage by having the following needs:

- Combination of two algorithms namely FFD and LAFF.
- 3D simulation displays.
- Simulations that can be used easily and quickly.
- Can determine the size of the container to be used.
- Can determine the form of goods to be packaged.
- Can determine the size of goods to be packed.

Here is the interface of simulation website when a user first the visit the website.

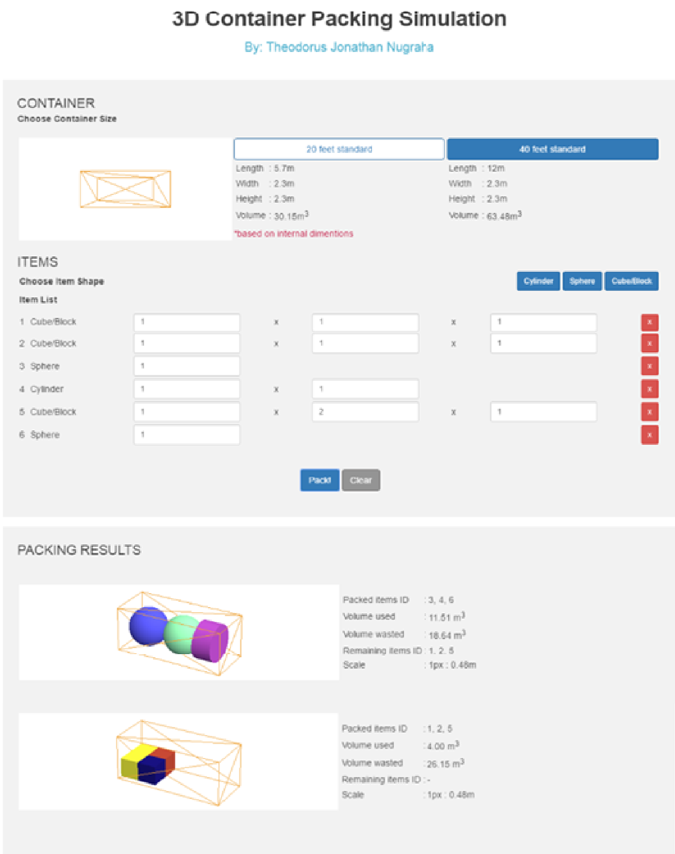

Figure 13: Website User Interface

Figure 13 shows how the simulation designed. This page is divided into two main parts, namely the input and output sections. The input section at the top of the page is the part where the user will input the simulation data. The required inputs are the size of the container, the shape of goods, and the size of the goods. Meanwhile, the output section at the bottom of the page is the part where the user can see the results of the simulation after they input the needed data.

In the Input Section, There are Several Buttons, among Others:

- Button to choose the size of the container that will be used is "20 feet standard" and "40 feet standard" button.
- Button to choose the shape of goods to be packed the button "cylinder", "sphere", and "cube/block". If the user wants to pack items with a tube or cylinder shape, the user will select the "cylinder" button. If the user wants to

pack the item with a sphere or sphere shape, the user will select the "sphere" button. If the user wants to pack the goods in the form of a box, the user will select the "cube/block" button. Each button will display a textbox that asks the user to fill the size based on the form that has been selected.

- The next available button is the "Pack!" button which will be used when user has done choosing the container size, selecting the item shape, and filling out all the desired item sizes. When the "Pack!" Button is selected by the user; the simulation website will display the simulation result. Before the simulation results are displayed, this website will check whether all required inputs have been filled by the user. If not all of them filled, the website will not display the simulation results.
- The last button is the "Clear" button used by the user when the user wants to delete all items that have been entered.

The result of this study is a simulation which can be accessed by open kemasin.com in an internet browser. This simulation can reduce the weakness of the LAFF packing method by combining it with the FFD packing method. Based on the results of the comparison that has been done, kemasin.com simulation is better in minimizing the empty space compared to simulation in the previous study. Table 2 describes the comparison before (simulation in the previous study) with after simulation build in this study.

Table 2: Comparison with Previous Study

Before	*After*
2D simulation display.	3D simulation display.
Only one item shape available, box.	Three item shapes available, cylinder, sphere, and box.
20 feet container size available.	20 and 40 feet container size available.
Using LAFF method.	Combination of FFD and LAFF methods.

CONCLUSIONS

This study has proved that the combination of two packing methods, first fit decreasing (FFD) and largest area first-fit (LAFF) is better than the previous study which only uses one packing method that is LAFF. Based on the simulation results that have been compared, this simulation is more optimal in reducing the empty space compared with the simulation designed in the previous study proved by the number of average wasted volume of less by 1.86 m^3. This study has also succeeded in making a simulation website from previously 2D to 3D, has featured two container size choices which are 20 feet and 40 feet, and three choices of goods shape which is a cylinder, sphere, and box which can be used and be running properly based on the test results done. Suggestions for further studies are to improve the features and simulation skills of packing goods, for example, is to use the database to store the simulation and add the number of containers that can be used.

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BIOGRAPHIES

Theodorus Jonathan Nugraha is an Alumnus at Universitas Multimedia Nusantara. Have experienced with simulation programing language like php and java. He can be reached by e-mail at theodorus.jonathan@student.umn.ac.id

Friska Natalia Ferdinand is Head of Research Center in Multimedia Nusantara University. Also Lecturer in Department of Information Systems. She received her Ph.D. in Industrial Engineering from Kyungsung University, Busan, Republic of Korea. Her teaching and research interests include system and analysis design, logistics, e- business and computer programming. She can be reached by e-mail at friska.natalia@umn.ac.id