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ORIGINAL ARTICLE

Interactive solution approach for loop layout problem using virtual reality technology

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Abstract Development of the manufacturing sector has sparked a wide interest in the study of facility layout problem since the past century. The traditional methods of solving facility layout planning are mainly numerical- and analytical-based simulation which might not reveal the actual situation of a manufacturing system. This paper proposed an interactive solution approach using virtual reality technology for loop layout planning to reduce the gap between numerical results and the real situation through enhanced human-machine interface. In this proposed approach, a virtual loop layout model has been developed as an intuitive and interactive platform for loop layout planning and evaluation in real-time control. This platform allows the user to modify the layout through direct interaction and evaluate the performance of the designed layout for multiple times to obtain the optimal layout design. A case study with the allocation of a shortcut conveyor in a loop layout in different locations conducted within the virtual platform has proven that this platform is an effective alternative solution tool for loop layout decision. The case study shows that the allocation of shortcut conveyor can improve the loop layout performance as it can reduce the traffic congestion of a part and reduce its travel distance by 18.77 %.

Keywords Virtual manufacturing · Virtual reality · Loop layout problem · Layout simulation · Real time

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1 Introduction

Facility layout problem is defined as the placement of facilities in the plant area which is known to have a significant impact in manufacturing performance from the cost and time aspect. In general, the mainstream resolution approaches that has been used to solve the facility layout in the past century mainly falls into four main categories which are exact procedure, heuristic methods, meta-heuristic methods and intelligence approaches [1]. Loop layout problem has been an undeniable major research trend in a facility layout problem study. Most of the resolution approaches that has been proposed is still based on a traditional approach such as an analytical- and numerical-based simulation method to obtain the best machine sequence for the manufacturing loop [2, 3]. The traditional approach mainly contains restrictive assumptions such as the actual distances between machines not important for the simulation which leads to the result that the final solution from the approach may not be adapted by many real manufacturing systems [2].

With the rapid growth of computer technology, a significant leap from the computerized numerical method to intuitive method through artificial environment generation for manufacturing system problem has been observed in the past decades [4]. The term virtual manufacturing gained popularity

Table 1 Machine specifications

Machine number	1	2	3	4	5	6	7	8	9	10
Length (unit)	5	1	6	1	5	4	7	5	3	4
Clearance (unit)	1	1	1	2	2	1	1	1	3	2

in early 1990s by the US Department of Defense Virtual Manufacturing Initiative. The specific definition of virtual manufacturing was given as integrated computer models that represent the precise and whole structure of manufacturing system and simulate their physical and logical behavior in manufacturing operation [5]. Now, the term broadly refers to the modeling of manufacturing systems and components with the effective use of computerized 3D model to simulate or design alternatives for an actual manufacturing system. Related researches on converting 3D model into virtual manufacturing [6] had supported the growth of virtual manufacturing technology.

The application of virtual reality in manufacturing system keeps expanding as the nature of virtual reality system that describes as three "I's": immersion, interaction, and imagination [7] serve as an intuitive and interactive method in plant simulation. Studies also showed that the virtual reality having graphic-based benefits in which accurately simulate the process in an intuitive way which cannot be achieve by other 2D solution method [8, 9] and provide interactive features for plant design [10]. In general, the scope and application area of virtual manufacturing has been categorized in three main areas which is design, operation management and manufacturing process [11]. In the area of operation management, virtual reality has been applied in plant layout visualization, simulation, modeling of the layout component, and evaluation of layout performance through the interaction between user and artificially generated environment, also known as virtual environment [9, 10, 12].

There are some studies [13–15] conducted to adopt virtual reality technology as the visualization tool to realistically simulate the layout design obtained from the traditional approaches in animation and 3D model. Results showed that the virtual factory model constructed in the studies which capable to realistically simulate the manufacturing process of real manufacturing system could assist plant layout decision maker to explore different potential production configuration and scheduling at significant saving of cost and time.

Table 2 Part specifications

Part type	Quantity	Label	Processing sequence
1	1	Red	2-1-6-5-8-9-3-4
2	1	Green	10-8-7-5-9-6-1
3	1	Blue	9-2-7-4

Table 3 Machine specifications

Part type	Processing time for each machine number (second)									
	1	2	3	4	5	6	7	8	9	10
1	3.4	2.6	5.3	6.7	5.2	6.4	–	7.2	3.0	–
2	6.0	–	–	–	4.8	3.8	3.1	6.5	2.5	7.2
3	–	4.3	–	6.3	–	–	3.6	–	4.2	–

However, the proposed studies mainly focus on virtual reality as visualization tool in plant layout design; instead, virtual reality should not only be used for visualization means but also for collaborative and communicative means [16].

This paper proposed the utilization of virtual reality technology in solving loop layout design problem which enhances the current or traditional approaches such as numerical and analytical simulation through 3D model simulation with the realistic consideration such as specific space requirement of each machine and the physic reaction of manufacturing element in real world such as the part-machine collision, friction, and gravity. Other than creating a realistic manufacturing system for the optimum solution testing in the virtual environment to enclosed the gap between optimum result and applicability of the result in real manufacturing system, the developed virtual manufacturing system platform also embedded with interactive features to that allowed the direct reallocation of machine sequence to improve the current simulated machine sequence after physical space consideration. A numerical result such as the number of congestion and total travel distance could be obtained from the virtual platform as the comparative data between initially tested machine sequence and improved machine sequence which assist in better decision making in loop layout design. A simulated case study was conducted to test on the usability of the developed virtual platform in two aspects, the interactive features and the realistic simulation on the impact of change in manufacturing system.

2 Loop layout test bed

A benchmark test bed has been designed [17] to evaluate the efficiency of numerical method in solving loop layout problems (solution effort and central processing unit (CPU) time). This benchmark test bed was use as a comparative platform by the researchers on the evaluation of their numerical method and the loop layout performance after applying the machine sequence obtained through the numerical method [18–20]. Total travel distance of the production part has been suggested to be another effective evaluation criterion for the loop performance for the benchmark test bed [21].

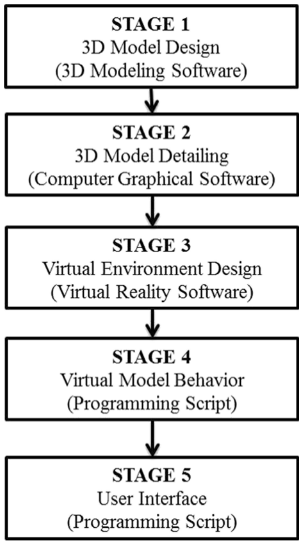


Fig. 1 Virtual loop layout development framework

The first phase of the test bed which has ten machines and three different production parts was adopted to be the basic design for the virtual loop layout platform. The details of the test bed such as the machine specifications and part specifications as the guideline for virtual loop layout development were listed in Tables 1 and 2, respectively. Table 3 would be the machining time for each part at each machine.

2.1 Evaluation criteria

The main purpose of optimum loop layout design was to improve operation performance by two common aspects which are minimization of material handling cost and reduction of total production time, to that purpose Aftentakis [22] had proposed and designed the traffic congestion as the main measurement for loop layout design. The congestion measurement appears to be a more effective indicator for the operation performance compared with the traditional facility design criterion such as lead-time, work in progress, or throughput; in other terms, the operational performance is driven by congestion [23] and the overall operational cost lowered by minimization of system congestion. This measurement had been used by multiple researchers [2, 17, 20, 24, 25] since it has been proposed till today; it had been recognized as the common measurement for evaluating a loop layout performance and standard indicator for loop layout design problem.

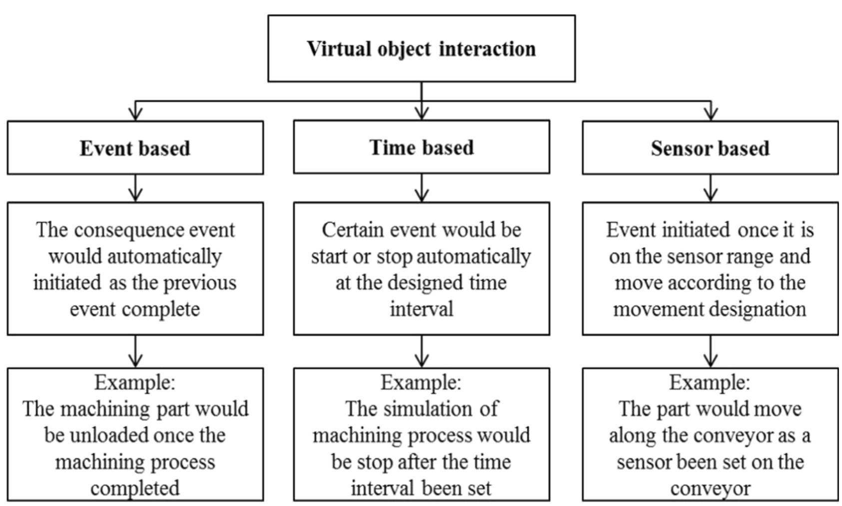
Thus, the first evaluation criteria of the loop layout that has been used in this test bed was traffic congestion which defined as the number of times a specific part traverses the loop before its processing is complete, denoted as Min_Sum [22]. The lower the number of congestion, the better the loop machines layout as the number of times the part travel through the loop to complete the process is reduced. The proposed objective functions for Min_Sum in the loop layout problem given in Eq. (1) were by [22]:

$$\mathrm{Cost}_{\mathrm{Min}_{\mathrm{Sum}}}(s) = \sum_{i=1}^{M} \mathrm{reload}_i \tag{1}$$

where s is layout solution, and reload$_i$ is the summation of reload for ith part.

In a manufacturing system, minimum travel distance is a key criterion to reduce overall material handling cost [26], travel distance of a product closely connected to overall lead times which the less distance product travels, the less time it takes to produce [27]. The total traveling distance of a part or materials has been used as the mainstream measurement for optimum layout design in cellular manufacturing design [28–30] as minimization of total traveling distance had impact the material handling cost and total productivity. Zuhdi [21] had proposed rectilinear distance used as an effective loop layout performance to the benchmark test bed that has been used in this study; thus, the rectilinear distance is a suitable

Fig. 2 Virtual object behavior



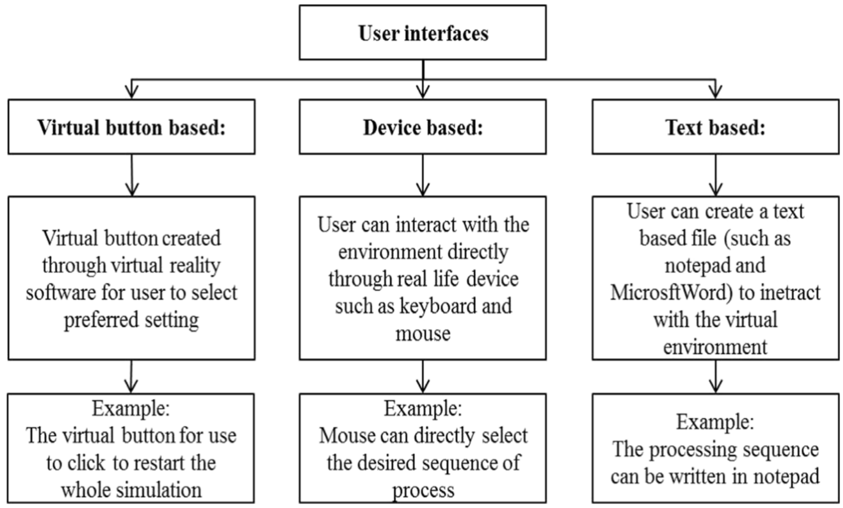


Fig. 3 User interfaces within virtual environment

measurement for the comparison between previous approaches with the proposed approach. The second evaluation method being used was the travel distance of a part for completing the manufacturing process. The travel distance of a part in the loop layout is considered as a rectilinear distance [21] in which a part can only travel in only one axial direction (horizontal or vertical) at a time. The rectilinear distance is expressed in the absolute value of x-distance and y-distance in Eq. (2):

$$d = |x - \alpha_i| + |y - \beta_i| \tag{2}$$

where d is the rectilinear distance of the initial location (x, y) to i location $(\alpha i, \beta i)$. Both evaluation criteria are used in the virtual loop layout model.

3 Virtual loop layout development

Figure 1 shows the framework for the virtual loop layout development which consists of five main stages. In the first stage, all the manufacturing system components such as material handling system (loop conveyor belt and shortcut conveyor belt), production parts, and machines are modeled as 3D objects according to the scale of the real model through commercial 3D modeling software. In this study, SolidWorks was use for the design of 3D model of the manufacturing component as this software is capable of providing precise scale for each component of the 3D model. All the designed 3D models were saved as a solidpart (SLDPRT) format that is ready to be exported to the computer graphical programming software for the detailing of the component. In the second stage, the detailing of the 3D model is necessary to create a more realistic

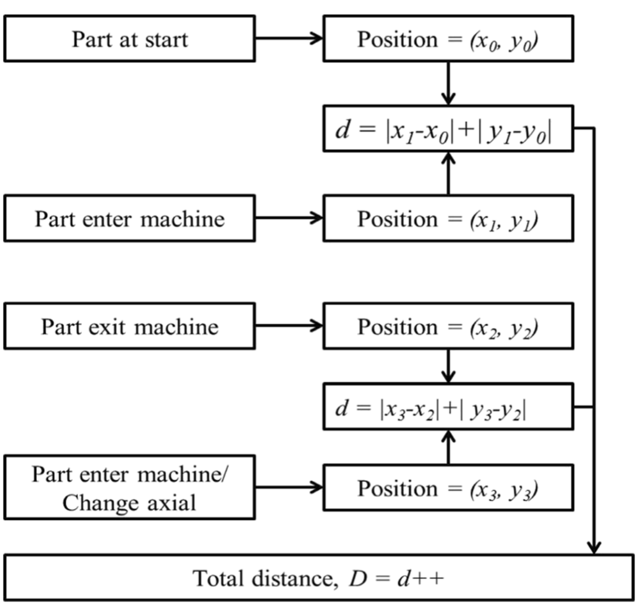


Fig. 4 Program architecture flow

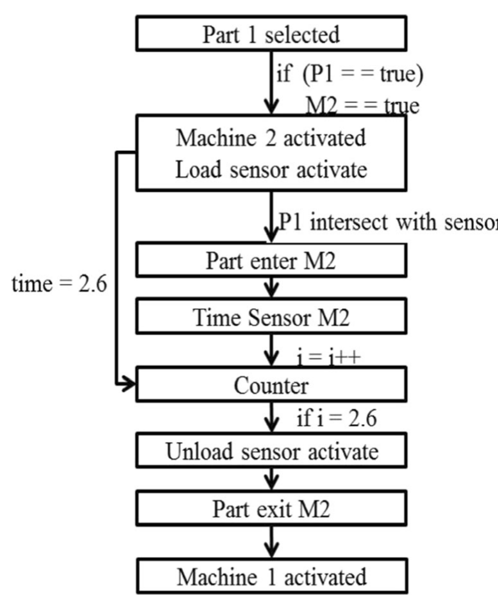


Fig. 5 Rectilinear distance feedback system

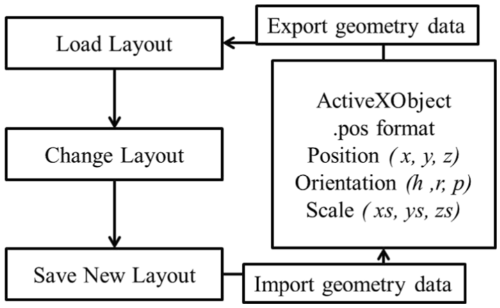


Fig. 6 Application of geometry data saving system

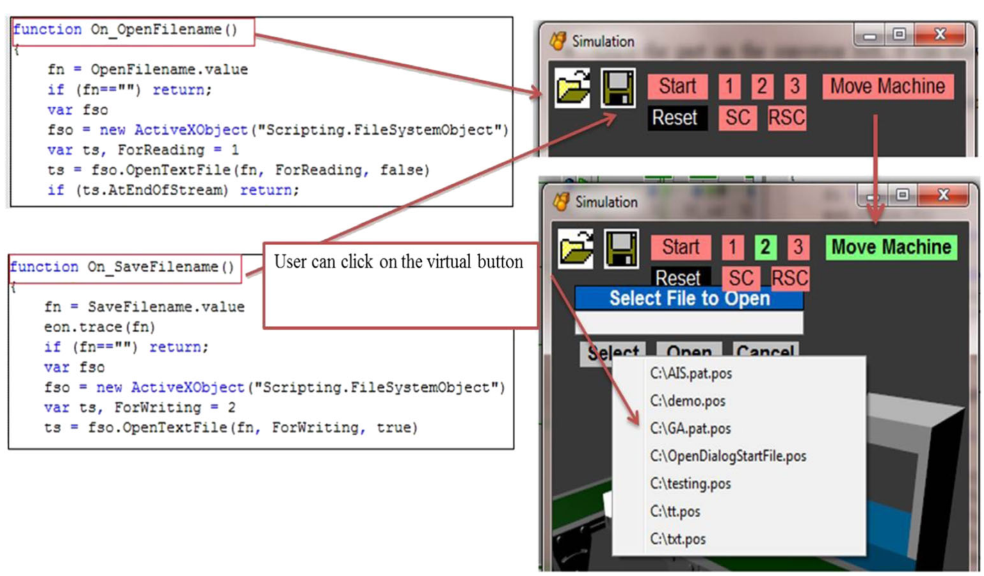
simulation environment. This second phase is achieved through the use of Autodesk 3ds Max commercial software for components texture detailing and geometry design of the complete loop layout. The complete layout is saved in stereolithography (STL) format before importing into the virtual environment. In the third stage, all the defined 3D models are imported into a virtual environment by utilizing commercial virtual reality software, EON Reality. All the geometry properties of each model in relation to other models such as position (axis x, y, z), orientation (yaw, roll, pitch), and the scale are decided. The physic engine of the virtual reality software is activated to define the physic of the 3D model (gravity, force, friction) and create a rigid body that enables the virtual environment to simulate the real reaction of each model in a real environment.

The fourth stage of the virtual loop layout development is the virtual model behavior decision, in which a specific programming language was used to program the reaction of each model. The behavior of each model can be triggered in three forms (Fig. 2) which are time-based triggered behavior, event-based triggered behavior, and sensor-based triggered behavior. The behavior of the part when exiting the machine is the time-based event, at which a time sensor and counter was scripted for sending the start pulse once it enters the machine and the counter has an increment pulse count until the number of counter is same as the desired processing time. The part will then be triggered to exit the machine. The selection of part and the sequence of the selected part is an event-based triggered behavior. Once the part type is selected, the sequence of part is triggered to identify the first processing sequence. Once the preceding machining process is completed, the next machine sensor is triggered to make the part enter the next machine in the sequence. To form the sensor-based event to happen, a virtual model in plate form is imported to the virtual environment and embedded with intersection collision detection features on the plate. Once the part is intersected with the virtual plate placed in front of the desired machine, the part is triggered to enter the machine for processing.

The fifth stage of the work frame is the creation of a user interface for the user to interact with the virtual environment. The created user interface includes the virtual button within the virtual environment and the device input such as keyboard and mouse control shown in Fig. 3. The user may click the virtual button for the selection of part and activate or deactivate the shortcut conveyor function. For the allocation of the machines sequence and shortcut conveyor position, the user can directly drag the virtual object to the desired location and simulate the impact of change in real time.

Figure 4 is the architecture to illustrate the programming flow of the virtual loop layout. As part 1 is selected, the script will activate machine 2. Then, machine 2 loading sensor is activated at the same time the processing time of the part (2.6 s) is sent to the counter. Part 1 then enters machine 2 as it intersects with the loading sensor. Time sensor is activated once the part has entered the machine and starts to send a pulse per second to the counter. Once the counter values are same as the machine time, the unloading sensor is activated. As the part exits machine 2, the

Fig. 7 Programming architecture for geometry data saving system



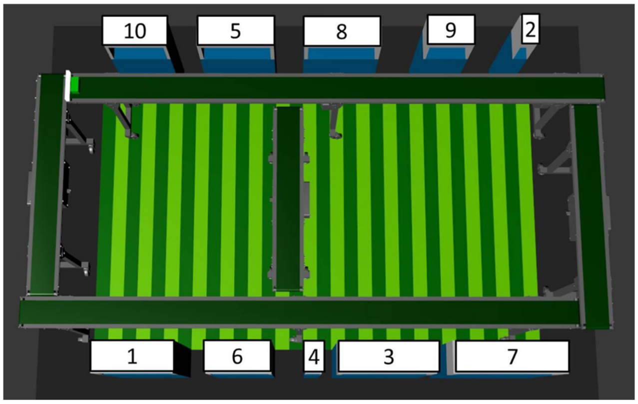


Fig. 8 AIS mode

next machine in the processing sequence (machine 1) is activated automatically. This programming will loop until the part completes the entire processing sequence.

3.1 Data feedback system

A data feedback system is designed to obtain the manufacturing data such as loop layout evaluation measurement to allow the allocation of machines sequence, allocation of material handling system, and finally the designed layout to be saved multiple times for simulation.

The feedback system designed for the calculation of traffic congestion is built by utilizing virtual object and programming script. A virtual model is created and scripted to be an intersection sensor. Once a part passes through the virtual object, the interaction trigger sends a signal to the counter. The scripted counter then calculates the total number of signal as the total congestion number for a part.

The data feedback system is designed to obtain the total travel distance of a part and requires the use of proximity sensor and a script that run on real time to calculate and display the real time distance a part has traveled. Four different sensors are placed in each corner of the loop conveyor and two sensors at each end of the shortcut conveyor to obtain the position of the part in real time. The distance is calculated through the rectilinear formula, which is the summation of the absolute data in *x*-direction and *y*-direction. The flow diagram of obtaining the rectilinear distance is described in Fig. 5.

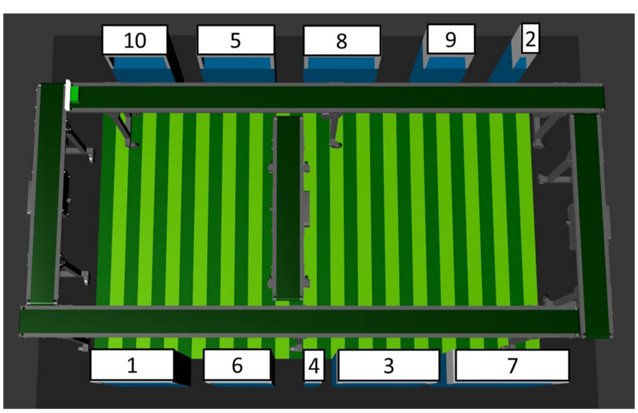


Fig. 9 GA-RMST model

ActiveXObject object (JavaScript) enables and returns a reference to an automated object; thus, the object function was used to save the geometry properties of each component in the virtual loop layout in position (POS) format after the allocation of machine sequence and material handling system by user decision which the programming flow design shown in Fig. 6 and the actual running interface and application of the programming script would be shown (Fig. 7).

4 Virtual loop layout validation

Two machine sequences were selected for the validation of the virtual loop layout model which were obtained through artificial immune system (AIS) [19] and genetic algorithm integrated with rectilinear Steiner minimum tree (GA-RMST) [21] which is listed in Table 4. The traffic congestion was calculated by the corresponding author while the results of the rectilinear distance were calculated through numerical methods by [21] for both sequences.

For the AIS model (Fig. 8), machine 10 is placed on the upper left corner, and machine 5 is placed on the right of machine 10 followed by machine 8, machine 9, and machine 2. Machine 7 (the sixth machine in sequence) is arranged at the lower row in the right corner, while machine 4 is arranged on the left of machine 7 followed by machine 1, machine 6, and machine 5.

For the GA-RMST model (Fig. 9), five machines were arranged on each row, where the upper row starts from the left corner with machine 10 followed by machine 8, machine 9, machine 2, and machine 3. At the lower row, the arrangement of machines starts from the left corner with machine 7 followed by machine 4, machine 1, machine 6, and machine 5.

The congestion number and rectilinear distance for the parts were obtained through the simulation according to the designed programming script flow for traffic congestion (Fig. 10) and rectilinear distance (Fig. 11). On the bottom of Fig. 10 showed the view in virtual loop layout model while the top part of the picture showed the sequence of programming flow. Once the part (green solid box) intersects with the congestion sensor (white plane), the intersection trigger would send signal to counter which set as increment counter to calculate the total number of a part intersects with the plane for completing the processing sequence, the counter would send the information after every intersection to the converter to convert the integer format as string format for the real time display of the data within virtual environment through 2DEdit text box. The programming script was used to rest the data to zero for the new testing cycle. The Fig. 11 shows the design of rectilinear distance data feedback system. In order to show the travel distance in real time within the virtual

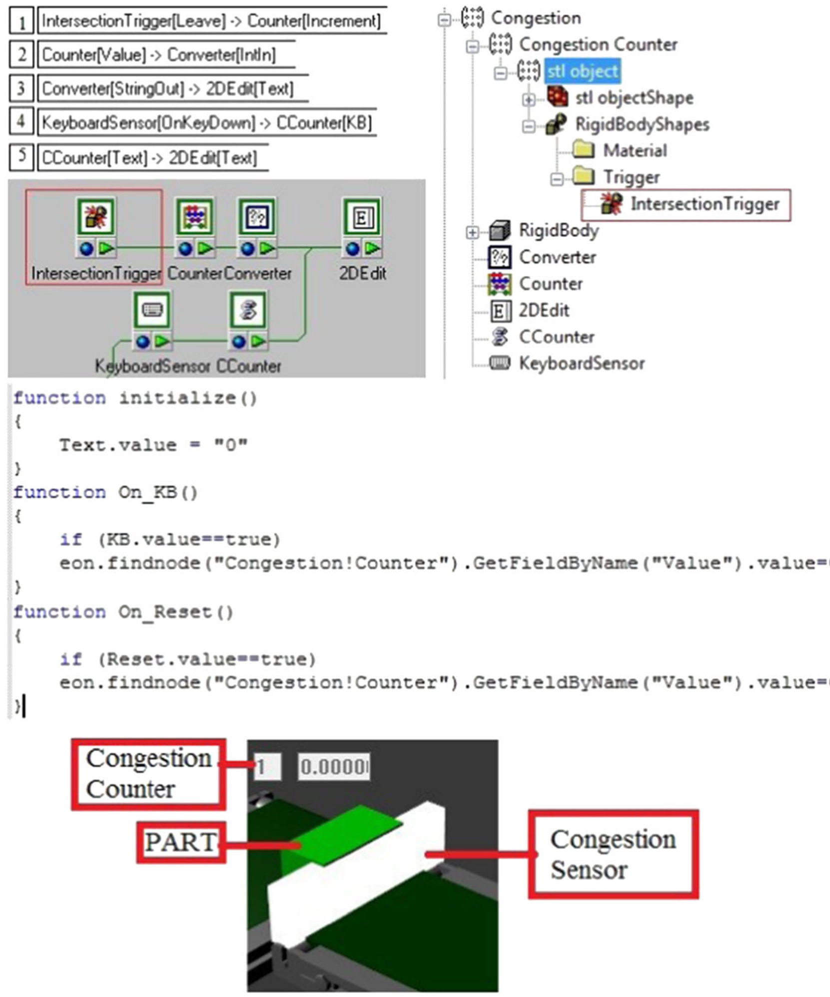


Fig. 10 Traffic congestion feedback sysytem

environment, the EventsProcessed function was utilized as it is a special subroutine in script for the virtual reality software which will be called during every frame only when at least one field of the script has changed its value since the last frame. The script showed how the initial value of the part has been set, and the new geometry data of the part was updated through a sensor placed on the conveyor belt that denoted as SensorA at every frame of simulation as the part keep moving. The script would obtain the distance of travel by subtracting the new geometry value of part from the initial geometry value of part. The upper right box in Fig. 11 is the initial value while the box below it was the new updated value of the part geometry, the log showed how the new data was updated according to simulation time while the bottom of the picture showed how the distance of part was displayed in virtual loop layout in real time.

The calculation method for rectilinear distance used by previous study was based on the assumption that the distance from the upper row to the lower row is only 2 units and the length of each row is limited to the summation length of machine unit and overlap clearance of the machine aligned on the row. While in the virtual loop layout simulation, the distance between the rows were 16 units and the length of the row were extended by 6 units on top of the summation length of machine unit and overlap clearance of the machine aligned on the row. There is an extra 20 units of rectilinear distance each time a part crosses from the upper row to the lower row or vice versa. Thus, calibration on the simulation data of rectilinear length to fit in the assumption is required for the data comparison. The calibration is as shown in Eq. (3):

$$d_c = d_s - 20\ \text{units} * R \tag{3}$$

where dc is the calibrated distance, ds is simulation distance, and R is the times the part cross from a row to another.

The percentage of difference of simulation data from the numerical data is calculated through the given Eq. (4):

$$\text{difference}\% = (d_c - d_n) \Big/ d_n * 100\% \tag{4}$$

where d_n is the numerical data.

As the previous section stated that in this research, the virtual reality technology is used as enhancing approaches for the current approaches by enclosing the gap between the

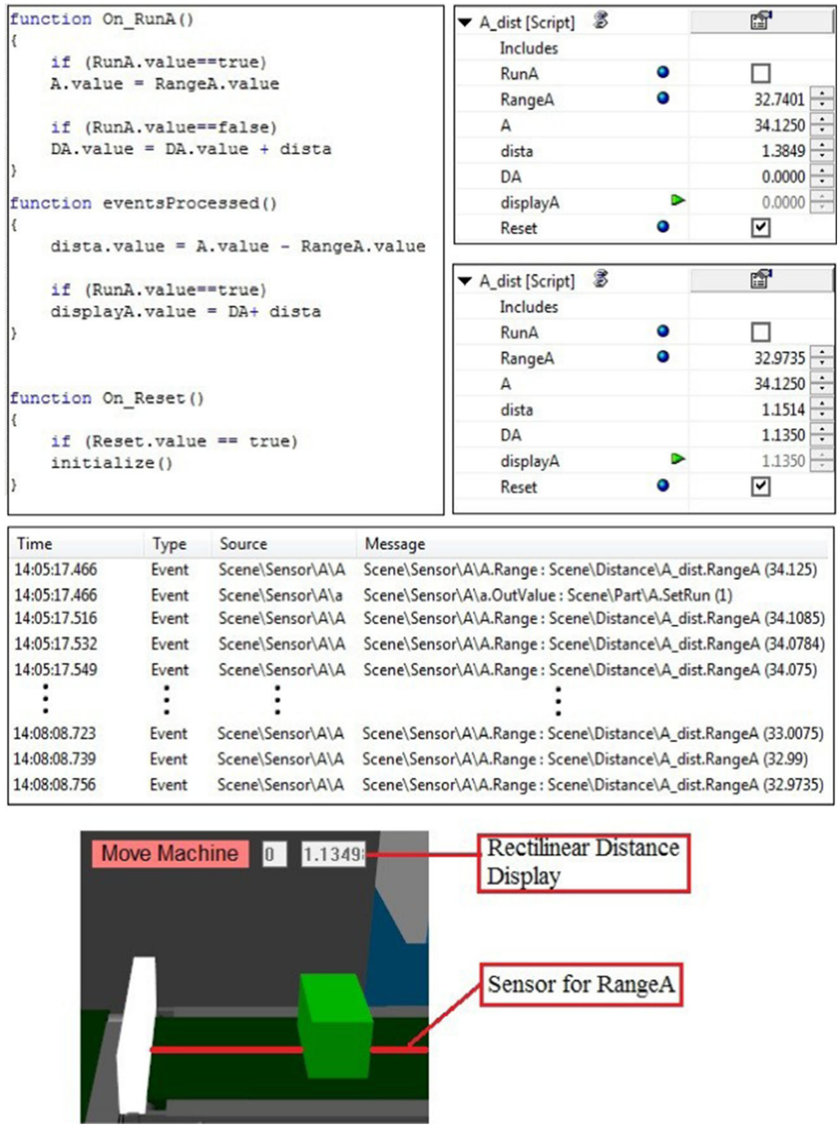


Fig. 11 Rectilinear distance data feedback system

optimum layout solution and the applicability of the solution to real manufacturing system. In Table 5, the optimum machine layout obtained by two current approaches (artificial immune system, AIS, and genetic algorithm-rectilinear minimum spanning tree, GA-RMST) has been tested in virtual reality platform, while the number of congestion and total

Fig. 12 Conveyor—location A

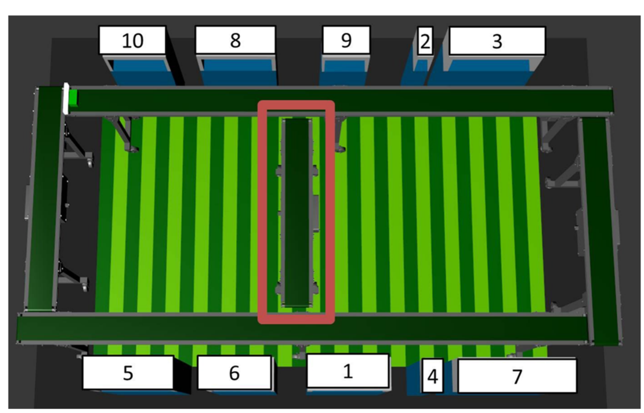


Fig. 13 Conveyor—location B

Fig. 14 Conveyor—location C

travel distance obtained from numerical method and virtual simulation was recorded. The significant difference between the distance obtained from numerical method, denoted as d_n and the virtual simulation data, denoted as d_s has been observed. The data from numerical data was made based on the ideal and restricted assumption which the travel distance for a part to cross from upper conveyor row to lower conveyor row is 1 unit [21]. While within the virtual conveyor system which constructed based on a scale-down mock up model of a real manufacturing system showed that the distance for a part to cross from upper conveyor row to lower conveyor row is 21 units. In order to validate this developed virtual loop layout model, a calibration on the simulation distance has been calibrated to be a calibrated distance, denoted as d_c according to the assumption that has been made in numerical method through the Eq. (3). As the percentage of difference of numerical data and calibrated data is negligible low (1.07 and 1.15 %); thus, this model is validated. In short, as the simulation data calibrated according to the assumption that has been made numerical data, the result would be almost the same.

This proposed approach reveals the gap from optimum solution to real case application, in which a part assumes to be traveled only 372 units in both machine sequences but instead the part had to travel in the range of 556 units in real manufacturing system. The interactive features of the developed platform enable redesigned of the current layout within the simulated scene, and the impact of change in the system could be simulated in real time without requirement of programming knowledge or algorithm. The visualization of the optimum solution and interactively redesign the layout in

Table 4 Machine sequence

Numerical method	Machine sequence	Congestion	Rectilinear distance
AIS	10-5-8-9-2-7-3-4-6-1	3	372
GA-RMST	10-8-9-2-3-7-4-1-6-5	3	372

virtual reality platform allowed decision maker to made further improvement on the current layout and making it more adaptive to be applied in real manufacturing system.

5 Case study

The virtual manufacturing system constructed in this study was based on the benchmark test bed proposed by [15] that continually used by other researchers [17, 20, 22, 31] and merge it to the mock up model of real conveyor system. The optimum machine sequence from different numerical approaches was simulated within the scene, conveyor shortcuts was suggested to further improved the optimum layout obtained from numerical method [21]. Previous studies on the related field which is the layout improvement in loop layout design had showed the significance effect of shortcut conveyor in reducing mean flow time by cutting the traveling time of job. Due to the reason that the benefits of shortcuts conveyor are only seen for best non-shortcut-based layout [32], most of the studies would use a solution algorithm to sort out the best layout and followed by another solution algorithm to determine the best set of shortcuts [33, 34]. This case study conducted based on the advice of previous literature work in which adds in conveyor shortcut on the optimum machine sequences for further improvement of loop layout performance in the aspect of reducing congestion and shorten total travel distance. The developed virtual platform directly input a 3D shortcut conveyor model into the optimum machines sequence layout, then the interactive features enable the free allocation of the shortcut conveyor in various location with realistic space restriction. Three possible locations for the shortcut conveyor were proposed which is placed in A (Fig. 12), B (Fig. 13), and C (Fig. 14) which the virtual model of shortcut conveyor can be placed to the possible location with the direct control from the user, and the virtual manufacturing system would be response in real time to adapt the impact of changes of the virtual environment. For location A, each end of the shortcut is located between machine 10–machine 8 and machine 6–machine 5, respectively. Location B is located between machine 8 and machine 9 to the middle of machine 1 and machine 6. Location C is bridged from the middle of machine 9 and machine 2 to the middle of machine 4 and machine 1. The shortcut conveyor can flow in two directions which transfers the part from the upper row to the lower row or vice versa.

The evaluation of loop layout performance for different location of shortcut conveyor conducted in real time without high level of programming and external solution algorithm had greatly reduced the development time for the search of

Table 5 Comparison between numerical and virtual simulation data

Machine sequence	Numerical data		Virtual simulation data				% of difference	
	Congestion	Distance, d_n (unit)	Congestion	Distance, d_s (unit)	Times part cross row, R	Distance, d_c (unit)	Congestion	Distance
AIS	3	372	3	556.0	9	376.0	0.00	1.07
GA-RMST	3	372	3	556.3	9	376.3	0.00	1.15

the best location of shortcut placement and is realistically tested in virtual reality platform could ease the installation of the designed system in real manufacturing plant.

The result for each location was obtained (Table 6). Based on the data, the traffic congestion was reduced for part 2 if the shortcut conveyor is placed in location A, while other locations of the shortcut conveyor do not have an effect on the congestion number. There is a noticeable reduction in rectilinear distance for part 2 in both shortcut location A and location C. In location A, the distance for part 2 reduced from 285.6 to 255.2 units, which is 10.64 % or 30.4 units of travel distance by using the shortcut. In location B, part 2 traveled less 53.4 units which is 232 units by utilizing the shortcut. This has a reduction of 18.77 % of travel distance compared with the travel distance without the shortcut (285.6 units). The total travel distance for part 1 and part 3 was not affected by the shortcut location where the travel distances maintain the same.

The data showed that the total travel distance and congestion number for all parts with a shortcut conveyor at location B were not reduced, and the loop performance was not improved by the allocation of a shortcut conveyor in location B. Thus, location B should be avoided from placing any material handling system as it should not be utilized to save manufacturing time and cost. Location A on the other hand can reduce both congestion number and travel distance, while location C does not reduce the congestion number but reduces a higher percentage of travel distance for part 2. The decision of choosing the best layout can be done through the simulation evaluation of loop layout in a virtual reality platform.

Table 6 Case study—data

Measurement	Part	Without shortcut	Shortcut location		
			A	B	C
Traffic congestion (number of times)	1	1	1	1	1
	2	2	1	2	2
	3	0	0	0	0
Distance (unit)	1	185.3	185.7	185.4	185.6
	2	285.6	255.2	285.1	232.0
	3	85.4	85.3	85.5	85.2

6 Conclusion

This paper proposed an interactive solution approach for loop layout problem using virtual reality technology to generate an interactive virtual environment that resembles the real loop layout system to visualize the elements in loop layout, simulating the manufacturing activities. The developed platform fully utilizing the 3D model of manufacturing elements provide an intuitive view on manufacturing system and providing interactive user interface that allowed the interaction between human machine in virtual space. These two features enhance the layout design phase through interaction with the virtual environment and evaluate the performance of different layouts in real time. The developed loop layout model in virtual reality platform was validated through data comparison of both simulation data and numerical data; the difference in percentage of the data was low, ranging from 1.07 to 1.15 % for rectilinear distance and 0 % for traffic congestion, proving the reliability of the simulation of the interactive platform. The case study conducted that focused on the allocation of a shortcut conveyor showed that virtual reality technology is an effective alternative solution tool to evaluate the performance measurement loop layout design through simulation in real time. Based on the study, the allocation of shortcut conveyor could reduce the total traffic congestion from a total number of three to two for a shortcut conveyor placed in location A and the travel distance of a part by 10.64 % in location A and 18.77 % in location C. The simulation result can predict the performance of a loop layout and provide the feedback data as a reference for the decision making of a loop layout design.

This interactive approach provides a more intuitive and interactive method to design a loop layout through providing a virtual loop layout for visualization of manufacturing elements in 3D model and direct control on the machine and shortcut location that involves human-machine interaction compare with other current numerical and analytical approach that decision maker unable to visualize and interact with the manufacturing system. The platform is also user-friendly as all the model behavior was pre-programmed and the user interface was created for real-time control on the virtual environment in which the modeling of current simulated layout does not require high level of programming skill or external solution algorithm. A more complete evaluation of the system usability and user perception would be conducted in future work for further improvement for this approach.

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