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The Development of Conceptual Design of Nurse Assistance Robot's Exterior with Ergonomic Approach

Pengembangan Konsep Desain Robot Bantu Perawat dengan Pendekatan Ergonomik

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Abstract

Nurses are human resources who have an important role in medical installations, especially hospitals. Nurses have various tasks such as assisting doctors in examining, treating and serving patients, and also other tasks such as administration. With these various tasks, physical and mental fatigue often occurs in nurses. To reduce the workload, robots have been used in hospitals around the world, especially in hospitals in Indonesia. This research aims to produce an initial concept for the exterior design of a nursing assistant robot using an ergonomics approach. The research methodology use product design and development framework, especially in conceptual design process which start from customer needs identification to design iteration. From the research it can be concluded that determining robot dimensions is based on anthropometric standards, user posture, hardware size, and so on. The main consideration in determining the size of the robot is the reach of the hand to pick up and store items, the range of the eye to see the interactive display screen.

Keywords: assistive robot, design, ergonomic.

***SDGs*:**

9 INDUSTRY, INNOVATION AND INFRASTRUCTURE

Abstrak

Perawat merupakan sumber daya manusia yang berperan penting dalam instalasi medis, khususnya rumah sakit. Perawat memiliki berbagai macam tugas seperti membantu dokter dalam memeriksa, menangani dan melayani pasien, dan juga tugas-tugas lainnya seperti administrasi dan lain-lain. Dengan berbagai tugas tersebut, kelelahan fisik dan mental kerap terjadi pada perawat. Untuk mengurangi beban tugas tersebut, penggunaan robot telah dilakukan di rumah sakit di dunia, khususnya juga di rumah sakit di Indonesia. Penelitian ini bertujuan untuk menghasilkan konsep awal rancangan eksterior robot bantu perawat dengan pendekatan ergonomi. Dari penelitian dapat disimpulkan bahwa penentuan dimensi robot berdasarkan standar-standar antropometri, postur pengguna, ukuran hardware, dan sebagainya. Pertimbangan utama dalam penentuan ukuran robot adalah jangkaua tangan dalam mengambil dan menyimpan barang, jangkauan penglihatan mata untuk melihat layar display interaktif.

Kata Kunci: robot bantu, desain, ergonomik.

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1. INTRODUCTION

Nurses are among the human resources who play an important role in health installations, especially in hospitals. They have main responsibilities in treating illnesses and caring for patients but also have other roles such as administrative tasks (Hasanah, Rahayuwati and Yudianto, 2020). With the evolution of the health industry and the profession, nurse work demands are increasing, which has the potential to make nurses physically and mentally exhausted. Moreover, as in previous COVID pandemics, the risk of contracting the disease from patients is very high (Bogue, 2011; Franch and Ferrer, 2021; Holland *et al.*, 2021; Mashudi, Izhar and Aris, 2022). Therefore, an integrated system is needed to support nurses in fulfilling their duties. Robotic technology is one option. Even after the pandemic, robotics in hospitals continues to develop (Suryawan and Adinandra, 2021).

Robotic technology has been used in hospitals for various purposes. Some robots perform simple tasks such as delivering food, medicine, documents, and goods (Tasaki *et al.*, 2015). Others are involved in disinfection tasks (Kaiser *et al.*, 2021; Aymerich-Franch and Ferrer, 2022) and telemedicine, communicating with doctors remotely (Herscovici *et al.*, 2007), such as the Terraio robot. More complex roles are performed by several robots, including health screening (Kaiser *et al.*, 2021; Aymerich-Franch and Ferrer, 2022) monitoring patient vital signs (Das, Sahu and Popa, 2017), patient rehabilitation (Qassim and Hasan, 2020) and tele-operation (Shi *et al.*, 2019). It is hoped that the use of these robots can reduce the risk of nurses contracting diseases from patients and alleviate the workload of nurses so that they can focus more on their main task of providing care to patients.

Some examples of robots that have been used on the market are Therapyo which was developed by Toyohashi University of Technology (Tasaki *et al.*, 2015). This robot functions to move around hospitals, delivering medicines, documents and other items. The use of robots has also been implemented in hospitals in Indonesia, especially since the COVID 19 pandemic in 2020. At the Metropolitan Hospital, Medical Center (MMC) Jakarta, TEMI robots have been used to assist visitors in finding locations and communicating between patients and nurses and doctors (MMC, 2022). At Pondok Indah Hospital (RSPI) Jakarta, Bellabot is used to help deliver food and drinks to visitors and patients (Syarifah, 2022). Apart from that, Pertamina Jaya Hospital uses two robots to assist doctors and nurses in intensive care, namely TEMI for patient communication and AMI for delivering food and drinks.

Therefore, this research aims to produce a similar robot concept to assist nurses' tasks. In designing the shape of a robot, ergonomic principles are required because it will interact with humans. To fulfill ergonomic principles, it is necessary to define the needs of humans, machines, and environmental elements (Wu, 2022) as shown in Figure 1, so that the robot design is contextually appropriate to the needs of nurses in hospitals. This definition will be implemented in the size, features, and shape of the robot that will be produced. Therefore, this research is focused on producing a nurse assistive robot design concept with ergonomic principles.

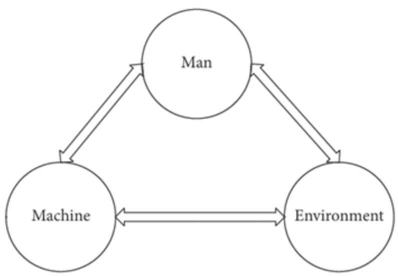


Figure 1. Three element of ergonomics design (Wu, 2022).

2. METHODOLOGY

This research is limited to the idea conceptualization stage, namely the stage where the user is defined, and the initial design is created. Therefore, the framework used refers to the stages of the product concept development process based on Ulrich and Eppinger with some adaptation as in Figure 2 as follows (Ulrich and Eppinger, 2015):

1). Customer Needs Identification.
2). Target Specification
3). Design Iteration
4). Final Specification

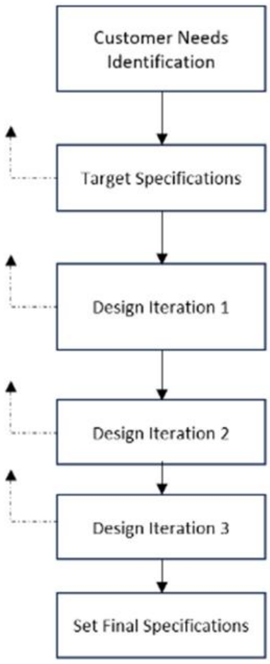


Figure 2. Conceptual design process (Ulrich and Eppinger, 2015).

2.1. Customer Needs Identification

This stage aims to identify customer needs through secondary data searches. The customer needs studied were divided into nursing needs (man element), robot technology requirement (machine) and environmental needs (environment). Nursing needs are limited to activity and anthropometry. Machine requirements are focused on robot hardware requirements and minimum dimensions. Environmental needs include the hospital interior and the condition of the building, especially the floors.

2.2. Target Specification

In this phase, target specifications are formulated based on user needs and comparisons with similar products (benchmarks) are carried out to determine the positioning of the product. The output is in the form of general sizes, material and component selection.

2.3. Design Iteration 1,2,3

This phase is summary of concept generation, concept selection and concept testing. In this phase the design concept is produced using an iterative process through sketches, 3D CAD models, prototyping and evaluation based on specifications. Design iteration 1 purpose is to build rough prototype for robotic system test. Design iteration 2 purpose is to determine overall dimension with ergonomic consideration and evaluation. Design Iteration 3 purpose to refine the shape in design iteration 2.

3. RESULTS AND DISCUSSION

3.1. Customer Needs Result

3.1.1. Task Analysis

The nursing activities that will be delegated to or supported by this robot are focused on repetitive activities delivering goods and intermediary information. During treating patients, nurse needs to carry several goods such as medicines, documents and medical equipment. Other goods to delivered to patients is foods and beverages. The dimension approximation of goods sizes as in Table 1.

Table 1. Size approximation.

No	Goods	Dimension Estimation (WxLxH)
1	Medicine	50 x 100 mm +-
2	Medical Equipment	Various
3	Document	210 x 297 mm (A4) (WxH)
4	Food Tray	300 x 400 mm +- (WxH)

This requires a compartment that can accommodate these goods. Especially for food, food in hospitals is generally delivered on trays. Other goods that delivered such as medicinie, medical equipment and document. In information intermediary activities, nurses are generally tasked with conveying information from examination results or requests from patients. Therefore, an integrated system is needed so that patients can interact directly with nurses, doctors or others without the nurse having to come to the patient's room. These 2 main tasks are required of robots.

3.1.2. Antropometric Analysis

This robot will interact with humans, especially nurses in hospitals, so determining the general size of the robot needs to consider human factors or ergonomics. Especially in anthropometry. Determining the dimensions of the robot considers the nurse's posture when interacting with the robot. Some interactions between nurses and robots include when nurses and patients pick up and store items; and when patients interact with nurses or doctors remotely via interactive displays.

These various interactions are carried out in sitting and standing postures. Meanwhile, other considerations include sleeping positions for patients. Some anthropometric standards and references that are relevant to this are as in the Panero standing, sitting and sleeping, arm reach and viewing area. Some of these standards become a reference in determining dimensions.

Apart from that, the nursing profession is generally female. In the standing position, it is hoped that female nurses of varying heights and hand reach can use it comfortably. Therefore, to determine the height and reach of the user's hand, the Design for Average principle will be applied. Meanwhile, in the sleeping position, it is hoped that patients with extreme low arm reach can reach. Therefore, we will apply a design for extreme women with a percentile of 50. Data on Indonesian anthropometric measurements from various percentiles can be seen in Table 2. The average body height of Indonesian women is 153 mm.

3.1.3. Robotics system overview

The working principle of this robot is as in Figure 3. In this figure you can see that this robot is divided into 2 component clusters, namely the robotic component cluster which consists of hardware and software components in the form of a drive module (Turtlebot), Rasperry pi, operating system, interactive display. Detail of robotics system are explained in another journal. Then there is a cluster of robot body components consisting of a frame, accessories and cover panels. All robotic components use components available on the market. The Lidar sensor functions to provide a signal if there is an obstacle ahead via a laser signal sensor that rotates 360 degrees. So that the robot can walk according to the hospital interior layout, the height of the sensor cannot be higher than the height of a table or chair (maximum +-750 mm).

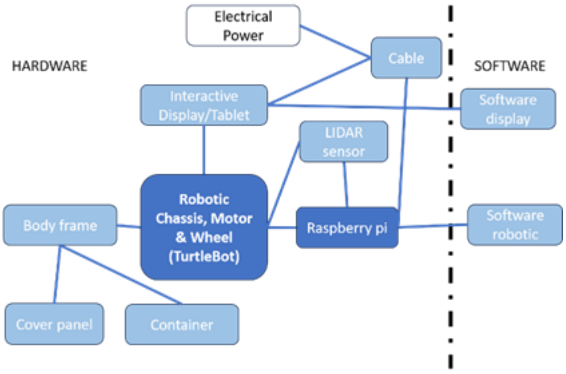


Figure 3. Robot schematics.

3.1.4. Standard layout and dimension of Hospital Interior and Furniture

This robot will operate alongside nurses in a hospital environment. Therefore, several interior size standards and hospital furniture need to be considered, especially in the hallways, patient rooms and nurses' stations.

According to Panero and Zelnik, there are no specific hospital hallway dimensions, because the hospital is a public place, it uses a horizontal circulation area for 2 wheelchair lanes from the public place with standard dimensions for the width of the aisle around the corridor area as the circulation area has a standard width of 1524 mm (Panero and Zelnik, 2014).

Then for standard sizes in the patient room area, based on Panero and Zelnik (Panero and Zelnik, 2014), as in Figure 4a, 4b, 4c. The entrance to the patient room is around 1168-1219 mm. Then the size of the bedroom circulation zone which is limited by curtains is around 2438 x 2515 mm with circulation zone in the side of bed about 762 mm. Then the height of the patient's bed is in the range of 500-800 mm.

Another area is the nurse's station as in Figure 4d, 4e. The seat height is 381-457 mm and the nurse's counter is 1067-1092 mm. Then as an additional reference, the dimensions of the goods storage cabinet as in Figure 4f, have a height of around 889-914 mm. These overall dimensions will be taken into consideration when determining the dimensions of the robot to be designed.

Table 2. The average anthropometric measurements data of Indonesian women aged 20-47 (PEI, 2013).

Dimension	Remarks	5th	50th	95th	Dimension	Remarks	5th	50th	95th
D1	Stature	117.54	152.58	187.63	D19	Hip breadth, sitting	21.65	32.32	43
D2	Eye height, standing	108.24	142.22	176.2	D20	Chest depth	9.73	19.22	28.71
D3	Shoulder height (acromion), standing	96.6	126.79	156.99	D21	Abdominal depth, sitting	11.02	20.58	30.14
D4	Elbow height, stand	73.13	95.65	118.17	D22	Shoulder-elbow length	21.85	32.04	42.23
D5	Hip height (trochanter), standing	55.33	87.3	119.27	D23	Abdominal depth, sitting	26.66	40.53	54.4
D6	Knuckle height, standing	48.58	66.51	84.44	D24	Buttock-knee depth, sitting	48.36	66.18	84
D7	Fingertip height, standing	40.56	60.39	80.21	D25	Forward grip reach	43.75	56.72	69.7
D8	Sitting height	60.93	78.1	95.28	D26	Head length.	10.77	17.91	25.05
D9	Sitting eye height	51.11	67.89	84.68	D27	Head breadth.	12.47	16.05	19.64
D10	Sitting shoulder height (acromion)	37.75	54.89	72.03	D28	Hand length	11.64	17.05	22.47
D11	Sitting elbow height	10.84	24.65	38.47	D29	Hand breadth	3.69	9.43	15.17
D12	Sitting thigh height (clearance)	3.75	14.7	25.65	D30	Foot length	14.59	22.73	30.87
D13	Sitting knee height	37.72	49.9	62.08	D31	Foot breadth	6.29	9.14	11.98
D14	Sitting popliteal height	30.1	39.88	49.65	D32	Span	111.41	152.71	194
D15	Sitting knee height	36.16	48.12	60.08	D33	Elbow span	57.17	79.88	102.59
D16	Sitting popliteal height	31.03	40.07	49.1	D34	Overhead grip reach, standing	138.32	185.76	233.2
D17	Shoulder breadth (bideltoid)	26.35	38.75	51.16	D35	Overhead grip reach,	80.24	113.42	146.61
D18	Shoulder breadth (biacromial)	15.44	31.32	47.19					

3.2. Target Specification Result

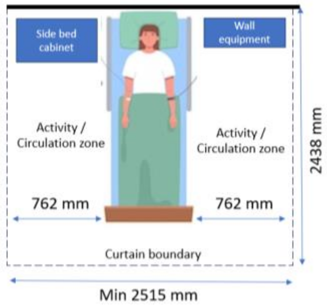
3.2.1. Benchmarking

A comparison with other robots on the market that have been operated in hospitals in Indonesia was carried out to compare the available features as shown in Table 3. The products compared are Temi, Amy and Bellabot. In terms of shape, Temi and Amy are humanoid, or resemble a human form, while Bellabot is not. Then functionally, Temi functions more as a visitor guide and communication agent. Meanwhile, Amy and Bellabot serve as delivery people for goods, food and drinks.

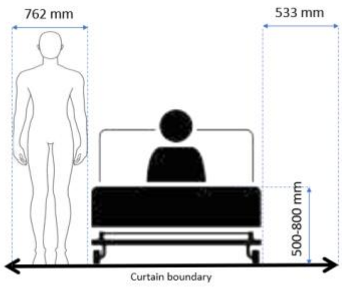
In terms of dimensions, the three robots have dimensions of 1000 mm and above. Amy is the tallest, namely 1740 mm. In terms of width, Temi is the most compact robot at 350 mm while Amy is the widest at 700 mm. In terms of features, Temi is the only one that has a teleconference feature but cannot carry items. Meanwhile Amy and Bellabot are able to carry items.

3.2.2. Target Specification

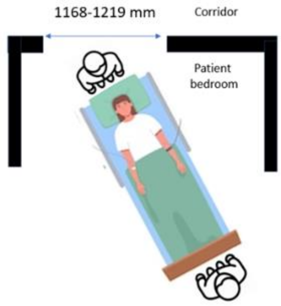
From these benchmarks, it is hopefully that the design concept will have more complete features, such as able to teleconference and carrying goods. Dimensions are expected to be as compact as possible.



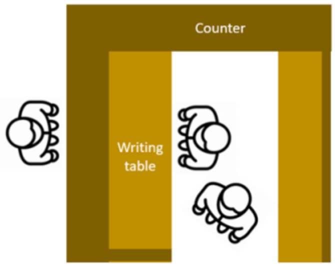
(a) Patient bedroom interior layout standard



(b) Patient bedroom interior layout standard front view

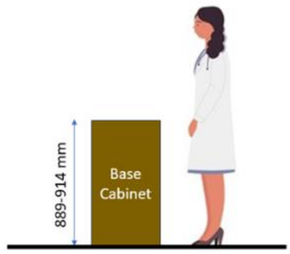


(c) Patient bedroom door dimension



(d) Nurse counter layout standard

(e) Nurse counter dimension standard side view



(f) Cabinet reachability dimension

Figure 4. Standar dimension (re-draw) (Panero and Zelnik, 2014).

Table 3. Competitor benchmark (VTRAC, 2004; Temi, 2023; Robotic, 2024).

Item	TEMI	AMY	BELLABOT
Picture			
Shape	Humanoid	Humanoid	Non-humanoid
Function	• Guide visitor to location • Communicator • Entertainment	Deliver goods, foods and beverages	Deliver goods, foods and beverages
Dimension (H x L x W) mm	1000 x 450 x 350	1740 x 940 × 700	1290 x 565 x 537
Features Tele-Conference	V		
Features Delivering food or goods		V	V

In carrying goods, it is hoped that the robot will not only be able to carry food trays but also other stored items so that nurses can send goods or medical medicines safely. The robot will operate in 2 scenario, when delivering goods and teleconferences. In the scenario of delivering goods as shown in Figure 5, robot operation begins with the officer/nurse storing the goods in a food tray or on a storage shelf. Then the robot is given the command to go to the patient's room, after which the robot will walk automatically to the patient's room. After arriving at the patient's room, the patient or nurse pick up items from the robot so that it can be used. In the teleconference scenario as shown in Figure 6, it starts with the doctor's assign nurse to teleconference with the patient. Then the robot is given a command, then walks automatically to the patient's room. The robot arrives at the patient's room, then the patient communicates with the doctor via teleconference via a display on the robot's tablet.

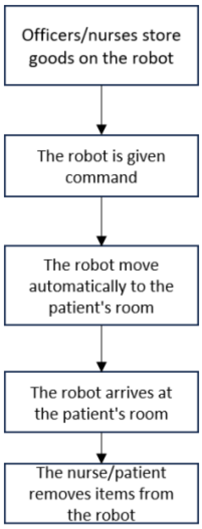


Figure 5. Scenario 1: delivering goods.

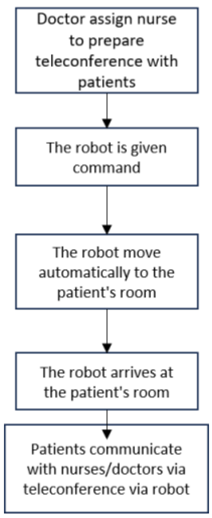


Figure 6. Scenario 2: teleconference.

From these various analyzes the specifications or design requirements are summarized as in Table 4. For customer needs, the ability to run automatically is implemented using a robotic system with various components mentioned previously. The ability to deliver goods is provided by containers for food trays or goods trays. The ability to communicate with patients is provided via an 8.7 inch tablet which includes a teleconference system. From an ergonomics perspective, the size constraints to be considered are the height from the floor to the container to determinde comfort for user hand reachability. The height from the floor to the interactive display also determined for visibility comfort for the nurse's and patient's. Other things are the width of the robot's body which are no more than the patient's room door dimension so it able to enter and exit and does not take too much space when moving in the corridor. The height dimensions of the lidar are expected to be no more than 500 mm due to the room layout, common obstacles, for example chairs and tables have this height dimension range. Apart from that, an attractive appearance will make nurses and hospital staff have a positive response.

Table 4. Target specifications.

No	Customer needs	Description	Specification
1	Able to move automaticly	• Robotic mobile system	• Turtle Bot • Lidar Sensor • Wheel
2	Able to deliver goods, foods and beverages	• Container	• Food tray • Cabinet
3	Able to be a communication tool between patients and nurses or doctors	Teleconference system	• Tablet 8,7 Inch • Tablet Holder
4	Ergonomic		
a	Floor to container dimension	According to hand reach in reaching items	>889 mm
b	Floor to interactive display dimension	According to eye's visual field	>889 mm (1000 mm)
5	Body dimension (L x W)	Depend on Turtlebot dimension	400 x 400 mm
6	Height position of LIDAR sensor		<500 mm

3.3. Design Iteration

This design iteration is a summary of the Concept generation, Selection and Development and Prototyping phases. The development process is implemented iteratively and gradually so that the team can simultaneously develop in their respective fields. Iterations were implemented into 3 iterations. The design process used CAD tools for designing 3D models and manual working for making prototypes.

3.3.1. First Iteration

In this first design iteration, the aim is to produce an initial prototype quickly for testing the function of robot components simultaneously with preparing specifications. Therefore, this iteration does not consider ergonomic aspects. The main considerations are the size of the robot hardware, key features such as the robotic drive system, wheels, containers, interactive displays and body. The general size of this design is 40 x 40 x 160 cm using L Profile hole material for the frame, multiplex for wood and acrylic for the door. The prototype for this first iteration is as shown in Figure 7 and Figure 8.

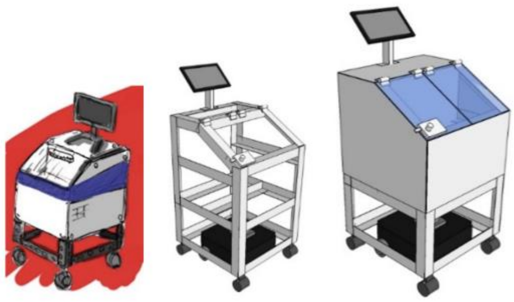


Figure 7. Sketch of first iteration robot.

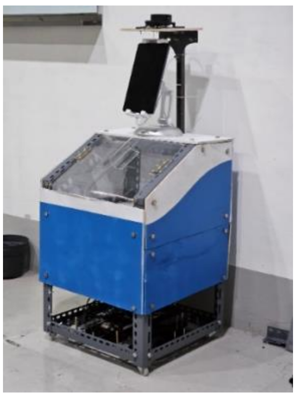


Figure 8. Prototype of robot iteration 1.

3.3.2. Second Iteration

In this second iteration, the aim is to produce a design that is more suitable from an ergonomic aspect, therefore the design refers to the anthropometric standards that have been formulated in the specifications, namely 400 x 400 x 889 mm (L x W x H). The main difference is the height of the robot, especially the height of containers for storing goods and interactive displays considering anthropometric measurements. Standard cabinet sizes as in Figure 4f, shelves are taken into consideration. Users, namely Indonesian female nurses with an average height of 50th percentile, can reach the robot comfortably. Another user is design for extreme, especially for the smallest patients, namely Indonesian women with the 5th percentile.

To validate the ergonomic level of the robot, a simulation was carried out using CAD software for. The Mannequin feature can simulate humans using the dimensions of a Chinese (Taiwanese) woman which is close to the size of an Indonesian woman based on data from PEI (PEI, 2013) in general as in Table 2.

Figure 9. Interaction with robot during standing posture.

Figure 10. Interaction with robot during seating posture.

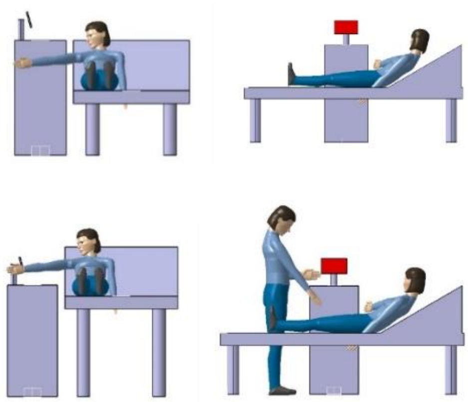


Figure 11. Interaction with robot during rest posture.

The simulated hand reach and viewing area in standing, sitting and sleeping positions as shown in Figure 9, Figure 10 and Figure 11. It was concluded that the reach of the hand to reach objects and the range of vision in standing, sitting and sleeping positions have different reach directions so that the design needs to accommodate these two postures as in Figure 9 and Figure 10. Apart from that, in sleeping positions, patients generally have different beds. The height can be adjusted, generally it has a range of around 500-800mm so it is not a problem when interacting with the robot display as in Figure 11. Therefore, it is concluded that the height for the goods storage container is 889 mm, it is not a problem, if added up to 900. Meanwhile, the height dimensions of the interactive display are around 45.7 mm from the bottom of the container, or around = 934.7 – 945.7 from the floor. For length and width, it refers to the size of the turtlebot hardware and the estimated frame. Turtlebot has dimensions of approximately 400 x 400 mm x so it is determined that the length and width are 400 x 400 mm. Therefore, the size of the robot is 400 x 400 x 900-950 (L x W x H).

3.3.3. Third Iteration/ Final Specification

This third iteration was purpose to improve the previous iteration. After defining the size, the detailed shapes of the robot are explored again. This third iteration resulted in a final design that is anthropometrically and looks better as in Figure 12, Figure 13, and Figure 14.

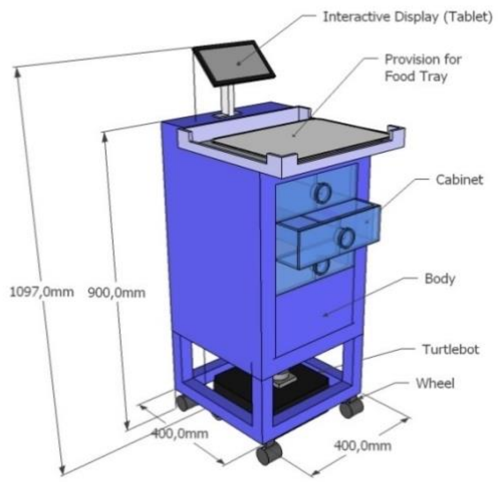


Figure 12. General dimension and description of design Iteration 3.

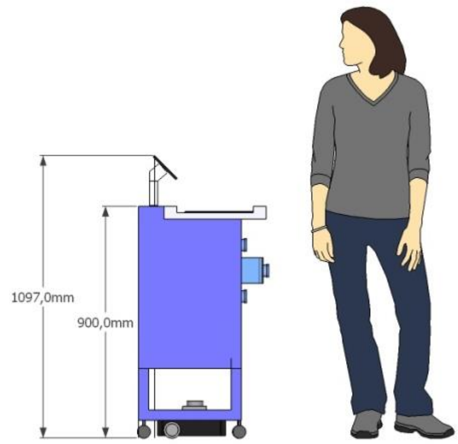


Figure 13. Robot and human 164 mm comparison.

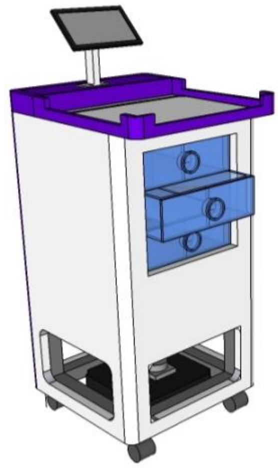


Figure 14. Final design refinement.

3.4. Discussion

Regarding this research focused to produce a nurse assistive robot design concept with ergonomic principle, the element of ergonomic consideration was determined (Wu, 2022). The result show that ergonomics consideration of man, machine and environment affect the robot's exterior dimension. Man consideration including task, anthropometry, and goods dimension should be considered to determined the ergonomics dimensiin of the robot. Machine consideration, such as robotic system and it's component also affect the minimum dimension and layout of the exterior due to specific function. Environmental consideration, such as hospital interior layout standard were also considered to ensure fitness between robot dimension and the interior of the hospital.

With various requirement to assist nurse task, consequencs include complexity and bulky shape. The robot concept offer multifunction which have a opportunity and risk. The opportunity lies in the robot's ability in assist various task, while the risk, involves complexity during usage or maintainance. In comparison to competitors Temi and Amy, this design concept appears bulkier, partly due to the use of turtlebot which may consume space during movement or storage when not in use.

Another consideration is that altough anthropometrics were considered (PEI, 2013), more specific requirement needs to be determined, especially in storage features. Currently it is not known what the priority of the goods is will be, which impact to the storage layout. For example, the frequently used equipement or goods, need to position in near top of the robot, while less frequent or less importance farther from top. According to various references (Tasaki *et al.*, 2015), it is also showed that build robot for medical uses requires cooperation with users, especially hospital institution to make the development effective.

4. CONCLUSION

According to this research, several conclusions can be drawn. First, determining the size of the robot design considers the task, user anthropometry, robot hardware and items to be carried by the robot. Second, the body posture of the nurse or patient when interacting with the robot as a reference for anthropometric measurements is the posture of standing, sitting, sitting in a wheelchair and sleeping. Third, the main activities from nurse or patients is interact with interactive display and pick up some goods from robot's container. According to that activites, Anthropometric measurements which used in this research is range of eyesight when standing, sitting and sleeping; and also hand reachability area when standing, sitting and sleeping. Fourth. The ideal height of the robot according to anthropometric standard is 889 mm or above.

The suggestions are as follows. First, in research, data collection still uses secondary data. Therefore, further research it is necessary to obtain primary data, especially feedback from nurses so that they can validate the suitability of the concept with user needs. The aesthetics aspect also able to develop for further research because the appearance of the robot is also important.

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