



DJJ5141 PROJECT 2

FINAL YEAR PROJECT REPORT

WITH THE TITLE

SMART WHEELCHAIR

SUPERVISED BY

MUHAMMAD FAIZ BIN ABDULLAH

TEAM MEMBERS

NAME	MATRIC.NO.
DEVARAJ A/L KALIANNAN	08DKM18F1056
TAMILANBAN A/L THAMILARASU	08DKM18F1050
MUHAMMAD AZRIQ BIN DOLMALA	08DKM18F1066

MECHANICAL ENGINEERING DEPARTMENT

JUN 2020

ACKNOWLEDGEMENT

We are really grateful because we managed to complete our project within the time given by our lecturer ENCIK MUHAMMAD FAIZ BIN ABDULLAH . This project cannot be completed without the effort and co-operation from our group members, TAMILANBAN A/L THAMILARASU and MUHAMMAD AZRIQ BIN DOLMALA. We also sincerely thank our lecturer or supervisor ENCIK MUHAMMAD FAIZ BIN ABDULLAH for the guidance and encouragement in finishing this project. Last but not least, we would like to express our gratitude to our parents, friends and respondents for the support willingness to spend some time with us to fill in the questionnaires.

ABSTRACT

Technology has made a drastic change in the medical field but there are still some people facing some problems. This wheelchair is fully automated and created specially for patients and elderly people. This is not only a smart wheelchair but also a deception wheelchair controlled by Arduino UNO with the support of some special equipments and system. This is created to solve some ridiculous problems such as physically disabled people face problems in moving and energy of patients are wasted in operating a manual wheelchair. Besides that, the helper becomes tired by pushing the wheelchair with patient. Moreover, patients easily get injured while shifting from wheelchair to bed. So the objective of this invention is solving the problem of three main people in one shot. They are the patients or disabled people, elderly people and also the helper. The basic methodology of this invention is two DC motors are fixed in the wheel to control the movement of the chair such as forward, backward and also sides movement. The Arduino is programmed to receive commands from voice recognition module and smartphone (Bluetooth) and operate the motor driver and motors. The movement of the deception part is controlled by another DC motor with the help of a switch. Through the findings, we found that our project has attracted many patients and peoples. Future recommendation of this project is adding safety features, increasing motor speed and multi controlling system.

Keywords: Smart wheelchair, Deception, Arduino UNO, Motor, Motor driver, Disabled and elderly people, Helper

ABSTRAK

Teknologi telah membuat perubahan drastik di dalam medan perubatan tetapi terdapat jua sesetengah orang masih menempuhi masalah. Kerusi roda ini berfungsi sepenuhnya secara automatik dan dapat mencipta sesuatu yang istimewa untuk pesakit dan orang tua. Kerusi roda ini bukanlah sahaja kerusi pintar tapi ia juga adalah kerusi roda sekadar penipuan yang dikawal oleh Arduino UNO dengan beberapa peralatan dan system yang istimewa. Ia juga dapat mencipta untuk menyelesaikan beberapa masalah yang berada di luar jangkauan seperti orang kurang upaya secara fizikal menghadapi masalah bergerak dan tenaga pesakit terbangun dalam mengendalikan kerusi roda manual. Selain itu, penolong menjadi penat dengan menolak kerusi tersebut. Jadi objektif penemuan ini adalah menyelesaikan masalah tiga orang utama dalam satu pukulan. Mereka adalah pesakit atau orang kurang upaya, orang tua dan juga pembantu. Metodologi asas penemuan ini adalah dua motor DC terpaku pada roda untuk mengawal pergerakan kerusi seperti pergerakan ke depan, ke belakang dan juga sisi. Arduino diprogramkan untuk menerima perintah dari modul pengenalan suara dan telefon pintar (Bluetooth) dan mengendalikan pemacu motor dan motor. Pergerakan bahagian penipuan dikendalikan oleh motor DC yang lain dengan bantuan suis. Melalui penemuan tersebut, kami mendapati bahawa projek kami telah menarik banyak pesakit dan masyarakat. Cadangan masa depan projek ini adalah menambahkan ciri keselamatan, meningkatkan kelajuan motor dan sistem kawalan pelbagai.

Kata kunci: Kerusi roda pintar, Penipuan, Arduino UNO, Motor, Pemandu motor, Orang kurang upaya dan warga tua, Helper

CONTENT

CHAPTER	CONTENTS	PAGES
	FRONT PAGE	1
	ACKNOWLEDEGEMENT	2
	ABSTRACT	3
	ABSTRAK	4
	CONTENTS	5-6
	LIST OF TABLES	7
	LIST OF FIGURES	7
1	INTRODUCTION	
	1.1 Research Background	8-9
	1.2 Problem Statement	10
	1.3 Objectives	10
	1.4 Scope	11
	1.5 Limitation	11
2	LITERATURE REVIEW	
	2.1 Introduction	12
	2.2 First wheelchair	13
	2.3 Second wheelchair	13
	2.4 'Bath wheelchair'	14
	2.5 The bicycle	14-15
	2.6 First portable wheelchair	15
	2.7 Power chairs	16
	2.8 Wheelchair sports	16
	2.9 All terrain wheelchair	17
3	METHODOLOGY	
	3.1 Introduction	18
	3.2 Explanation	18-19
	3.3 Flow Chart	20-21
	3.4 Product & Design	22-26
	3.5 Budget	27

	3.6 Gantt chart	28-30
4	FINDINGS AND ANALYSIS	
	4.1 Introduction	31-32
	4.2 Survey	32-35
	4.3 Survey Conclusion	35
5	DISCUSSION , CONCLUSION AND UPGRADE PLAN	
	5.1 Introduction	36
	5.2 Discussion	36-38
	5.3 Upgrade Specification	38
	CONCLUSION	39
	REFERENCES	40

LIST OF TABLES

CONTENT	PAGE
Table 1.0 – Budget Calculations	27
Table 2.0 – Project Activity	29-30

LIST OF FIGURES

CONTENT	PAGES
Figure 1.1 – FIRST WHEELCHAIR	13
Figure 1.2 – SECOND WHEELCHAIR	13
Figure 1.3 – THE BATH CHAIR	14
Figure 1.4 – THE BICYCLE	15
Figure 1.5 – FIRST PORTABLE WHEELCHAIR	15
Figure 1.6 – POWER CHAIR	16
Figure 1.7 – WHEELCHAIR SPORTS	16
Figure 1.8 – ALL TERRAIN WHEELCHAIRS	17
Figure 2.1 – PROJECT FLOW CHART	20
Figure 2.2 – MOVEMENT CONTROL FLOW CHART	21
Figure 3.1 – PROJECT DESIGN	22
Figure 3.2 – PROJECT DESIGN	23
Figure 3.3 - PROJECT	24
Figure 4.1 – WHEELCHAIR IN SITTING POSITION	25
Figure 4.2 – WHEELCHAIR IN RESTING POSITION	26 31
Figure 5.1 – PIE CHART	

CHAPTER 1

INTRODUCTION

1.1 RESEARCH BACKGROUND

In this modern era, it is true that recent developments of science and technology has drastically changed the way of a normal person lives his life but we also have to accept that there are certain groups of people who have to not been benefit from this development. One particular handicapped people with have limited mobility and some elderly people are still living a miserable life.

The engineers have taken many steps to help those people like designing a wheelchair. Recently, the elderly person and physically handicapped person who use a wheelchair are increasing. However, only two type of wheelchairs were came into wide use. They are normal hand operating wheelchair and electronic wheelchair operated by joystick. The former type needs muscular strength for the operation and the latter type needs the skill. Not only that, the handicapped without hand need help of another people to move the wheelchair.

Not only that, we also found that lifting and shifting of a disabled or a bedridden person has always been difficult, risky and problematic. This lifting and shifting is also dangerous and painful for that particular disabled person if an untrained person does it. Moreover, patients are also afraid of this procedure, as there is possibility in danger of slipping, falling and getting injured.

In the hospitals, this lifting and shifting is strenuous for nurses when he or she is trying to lift a patient. The nurse has to bend over the patient in order to lift him. This posture in the long run may also give nurses back pain which can lead into permanent back problems. A lot of medical literature is available on back problems of nurses as it is very common in nurses nowadays.

Many lifting and shifting apparatuses are available in the market but all these apparatus are expensive and it will be a troublesome to people with an average income. Not only that, it is also unpractical at home as it takes a lot of space and a lot of training for the user.

So this shows us that people not only faces problem in operating a wheelchair but also in taking rest.

Therefore, we as a team have designed a smart wheelchair. This smart wheelchair aims to provide aid to those handicapped and elderly people by providing them with some sort of mobility which would greatly help them and also reduce the burden of the person who helps to push the chair. So, we have designed a wheelchair which can be operated by voice and smart phone with the help of voice recognition module and Bluetooth connector. Moreover, we have add a special feature in our wheelchair. This wheelchair not only to move, it also can be used as a deception wheelchair to take rest.

1.2 PROBLEM STATEMENT

- 2 Physically disabled people face problems in moving with a manual wheelchair
- 3 A lot of energy wasted by the patient in operating manual wheelchair
- 4 The helper easily becomes tired by pushing the wheelchair with patient continuously
- 5 Elderly and disabled people get a backbone pain when always sit in a fix position.
- 6 Patients cannot take rest on wheelchair and easily get injured while shifting to bed.

Cause of Problem:

The root of these problems is the lack of mobility in the manual wheelchair design. Actually, a normal wheelchair contain a mass around 30kg and above. It becomes double when a patient sits on it. So, it will be though for the disabled people and also patients to move a wheelchair with load. Even the helper will feel tired to push the wheelchair with patient for a long time. Not only that, a wheelchair is only designed to sit and not to take rest. The sitting position of the wheelchair also cannot be adjust. So, patients have to be shifted from wheelchair to the bed.

1.3 OBJECTIVES

- I. To provide the facilities for disabled people and elderly people who cannot move properly.
- II. To develop a wheelchair which can be controlled by voice and Bluetooth.
- III. To reduce the burden of the people who push the wheelchair.
- IV. To improve the balance and posture stability of old age people
- V. Prevention of incapable of surviving serious injuries

1.4 SCOPE

- I. To be used by handicapped especially paralyzed patient and elderly people to move with just voice command (voice control).
- II. To be used by patient with talking disorder (dumb) by Bluetooth control in a short distance.
- III. To help medium weight people to move with a control and consistent speed.
- IV. To adjust the resting position when needed.
- V. To convert the wheelchair from sitting position to sleeping position in particular angle.

1.5 LIMITATIONS

- I. Due to problem of gear, higher weight cannot be supported.
- II. Speech synthesizer cannot be performed at noisy environment.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Several studies have shown that the independence mobility access the benefit to both children and adults. Independent mobility increases vocational and educational opportunities, reduces dependence on caregivers and family members, and promotes feelings of self reliance.

For young children, independent mobility serves as the foundation for much early learning. Non ambulatory children lack access to the wealth of stimuli afforded self-ambulating children. This lack exploration and control often produces a cycle of deprication and reduce motivation that leads to learned helplessness.

Wheelchair is one of the best creation to provide independent mobility, but the idea of creating wheelchair is not a new one. It was started many years ago. These are the cycle of development of wheelchair:

2.2 First wheelchair



FIGURE 1.1

- First record of combining wheels to furniture
- Image on Greek vase of wheeled child's bed
- 530 B.C

2.3 Second wheelchair



FIGURE 1.2

- Three centuries later in China; the Chinese used their invented wheelbarrow to move people as well as heavy objects.
- A distinction between the two functions was not made for another several hundred years, around 525 C.E. when images of wheeled chairs made specially to carry people begin to occur in Chinese art.

2.4 The “Bath” Chair

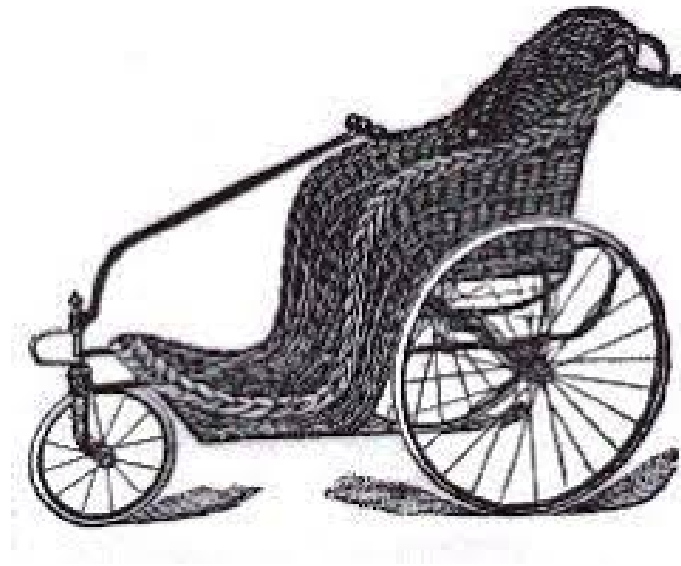


FIGURE 1.3

- Developed in Bath, England.
- Invented by John Dawson in 1783.
- It had 2 large rear wheels and one small front wheel.

2.5 The Bicycle

- 1790, de Sivrac introduced the “swiftwalker”; a wooden bicycle propelled by the user by pushing feet to the ground.
- In 1865 cranks and pedals were added and it was re-named the “boneshaker”.
- Like the wheelchair, the bike is also propelled by user.



FIGURE 1.4

2.6 First Portable Wheelchairs

- Harry Jennings and his friend Herbet Everest, both mechanical engineers, invented the first lightweight, steel, collapsible wheelchair in 1933.
- The two saw the business potential of the invention and went on to become the first mass-manufacturers of wheelchairs; Everest and Jennings. Their “x-brae” design is still in common use.



FIGURE 1.5

2.7 Power Chairs

- An electric-powered wheelchair is a wheelchair that is moved via the means of an electric motor and navigational controls, usually a small joystick mounted on the armrest, rather than manual power.



FIGURE 1.6

2.8 Wheelchair Sports

- Were originally introduced as a form of therapy in a Rehab hospital in England.



FIGURE 1.7

2.9 All Terrain Wheelchairs

- All-terrain wheelchairs allow users to enter the water and provide a better mobility on beach sand and on uneven terrain, and even snow. The common adaption among the different designs is that they have extra-wide wheels or tires, to increase stability on uneven or unsteady terrain. The wide tires on snow wheelchairs, for example, spread the weight of the chair user and the chair over a wider surface, similar to how snowshoes perform the same purpose for someone on foot, allowing the person to travel on top of the snow rather than sinking.



FIGURE 1.8

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

What is methodology? A methodology is a plan-of-attack, especially when that plan-of-attack is used repeatedly. This might be obvious, but the word methodology is related to the word method. In fact, a methodology is a system of methods followed consistently. Scientists, for example, use various methodologies as they perform experiments. It might seem like the world is nothing but chaos and disorder. But actually, sometimes there is a method to this madness. And sometimes there's a methodology.

In this chapter, there will be a lot of information about the process and journey through out the making of our final project. There will be flow chart showing the process of us making the whole project. This flow chart will explain the processes we took. Next, is the Gantt Chart, which will show the actual and planning throughout all the 13 weeks of our final year project journey.

3.2 EXPLANATION

The Smart Wheelchair is designed and completed by the complete methodology which were our guideline throughout this project. The flow chart of this methodology is shown in figure1.

First of all, we had conduct a brief explanation with our Supervisor(Penyelia) to refresh and make a complete study about our project. Then, we had small meeting between our own teammates to plan our daily and weekly task and duty according to the gantt chart. We also divides the duty equally. After that, we use the workshop in Mechanical Department of Politeknik Shah Alam for few weeks to make our wheelchair body. Before that, we bought some plates and rods which will be used to make the body with the MIG welding process.

After complete welding the body, we connected two big wheels at the wheelchair with a help of long rod. We also place two small wheels at the front which can move freely to help the wheelchair moves in all angle. While welding the body, we connected the back plate of the wheelchair to a dc motor with plates. So. it will gives the appearance of deception part. We connected a bidirectional switch with that dc motor, so that the patient can adjust the angle of the wheelchair according their comfort. Since the deception part is over, we move to the smart system part. We make own coding with Arduino IDE software and test it on small dc motors with android mobile app. We also able to control those motors with voice controller with smartphone. Voice recognition module cannot be operate in a noisy environment and it also wont receives commands from other than the person who do the coding. This is because voice recognition module can only operated with single voice. So, we have change our idea to operate the wheelchair with smartphone voice control. After success controlling the dc motors, we use the same codes to control power windows which will be used to move the wheelchair. The power windows are fixed at the wheelchair and connected to the wheels with a chain, so the wheel will rotates together with power window when receives command. Not only that, we placed a on/off switch at the power supply to connect and disconnect the power supply.

HOW TO OPERATE

Step 1: The first step to use this “Smart Wheelchair” is to turn on the power switch. Then we should connect the bluetooth module in the arduino system of the wheelchair with the smartphone.

Step 2: After that, we have to sit on the weelchair and adjust the position of it with operating the bidirectional switch placed in the wheelchair. Then, we should open the arduino controlling app which were download earlier and connect it with the arduino.

Step 3: Finally, we can operate the smart wheelchair with smartphone like operating a remote car and also can operate it with smart phone voice commands. Depends on the person operating it. We also can change the wheelchair into a bed or deception wheelchair by operating the bidiversional switch to take rest.

3.3 FLOW CHART OF “SMART WHEELCHAIR”

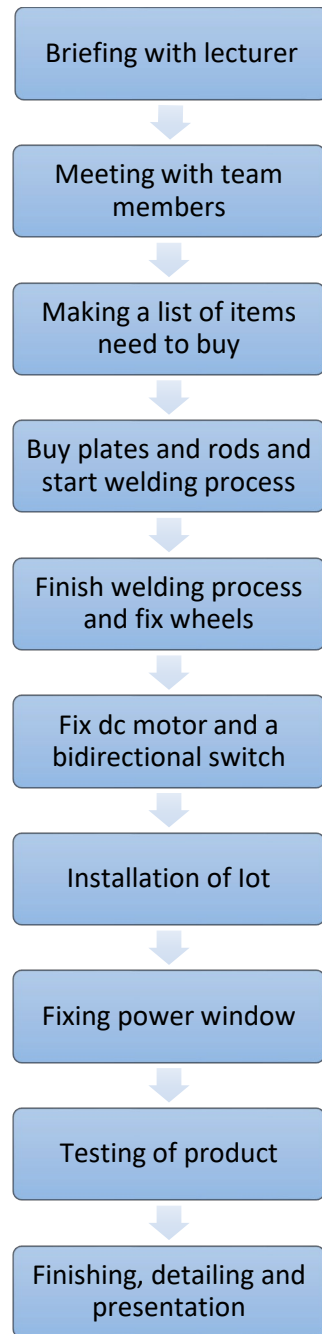


FIGURE 2.1: PROJECT FLOW CHART

METHODS (MOVEMENT CONTROL FLOW CHART)

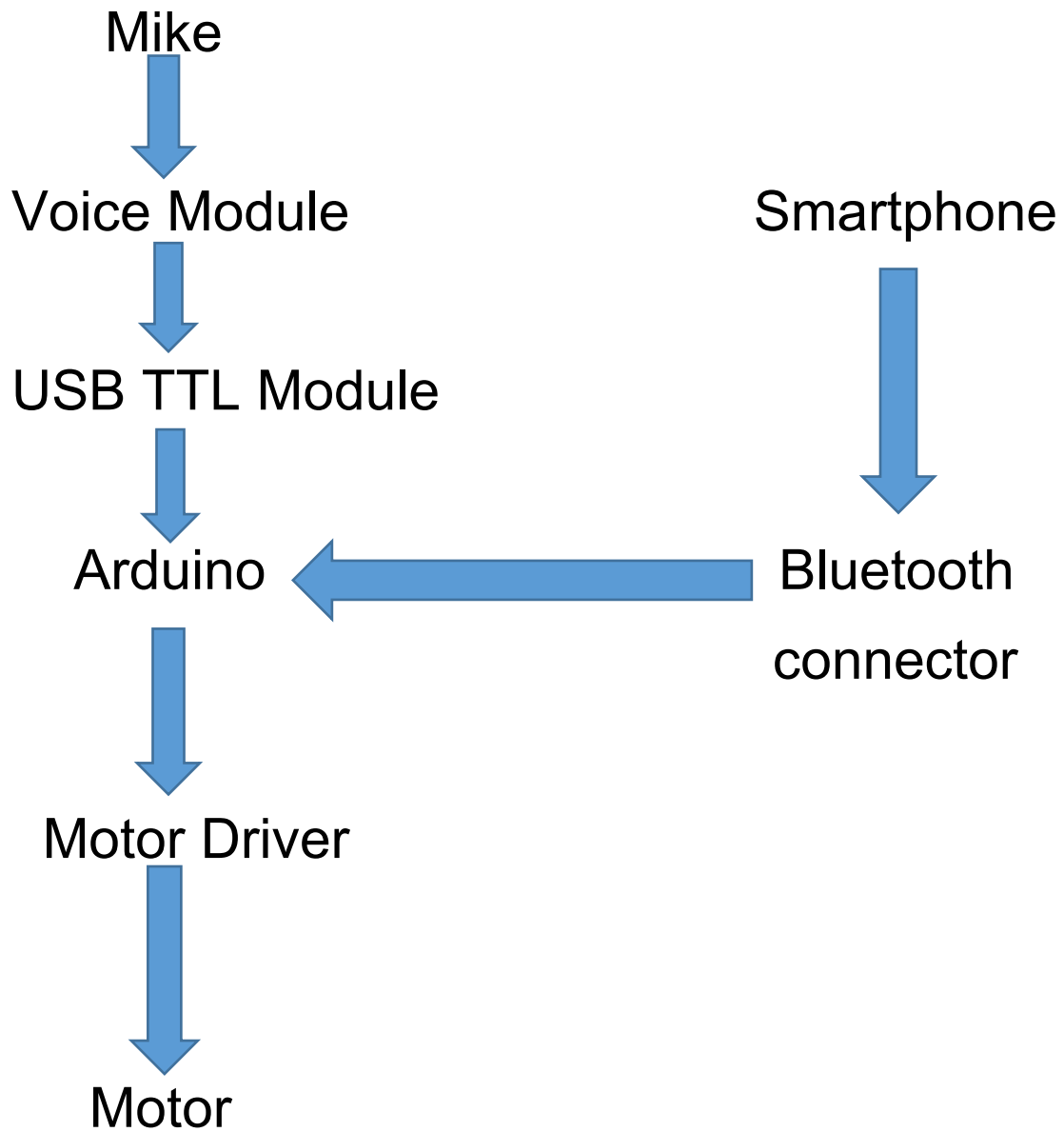


FIGURE 2.2

3.4 “SMART WHEELCHAIR” DESIGN AND PRODUCT

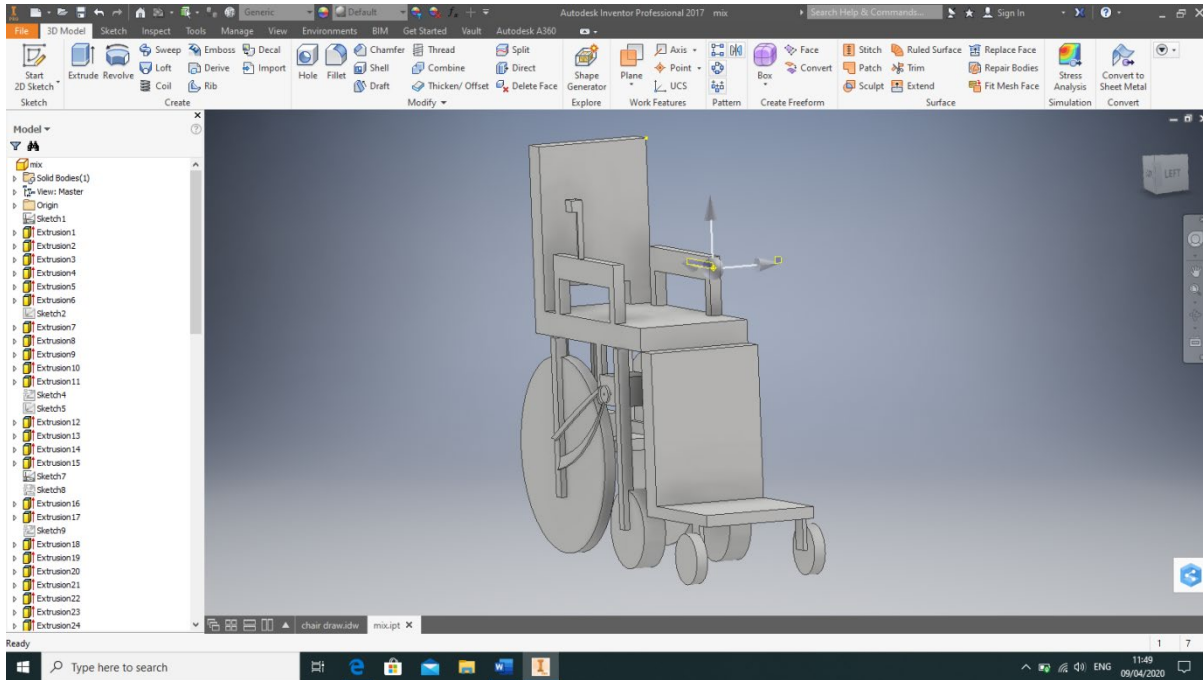


FIGURE 3.1

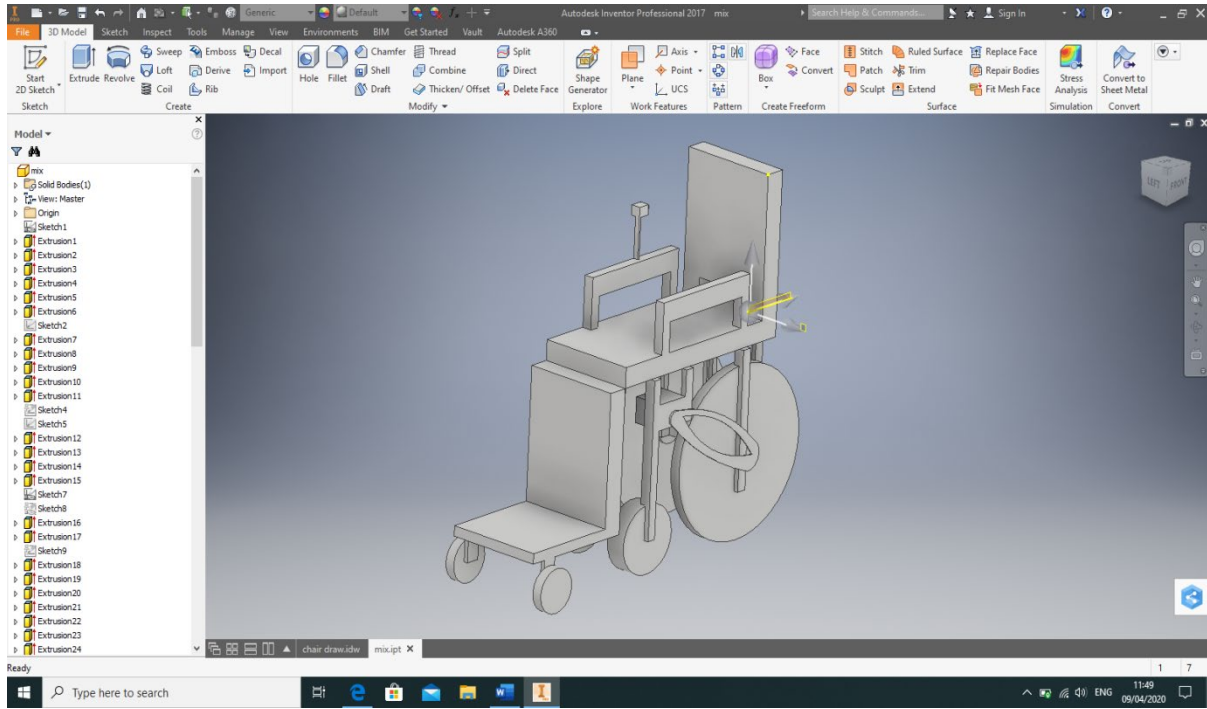


FIGURE 3.2



FIGURE 3.3

ANALYSIS OF PROJECT DESIGN

PROJECT DESIGN (DECEPTION WHEELCHAIR) IN DIFFERENT POSITION

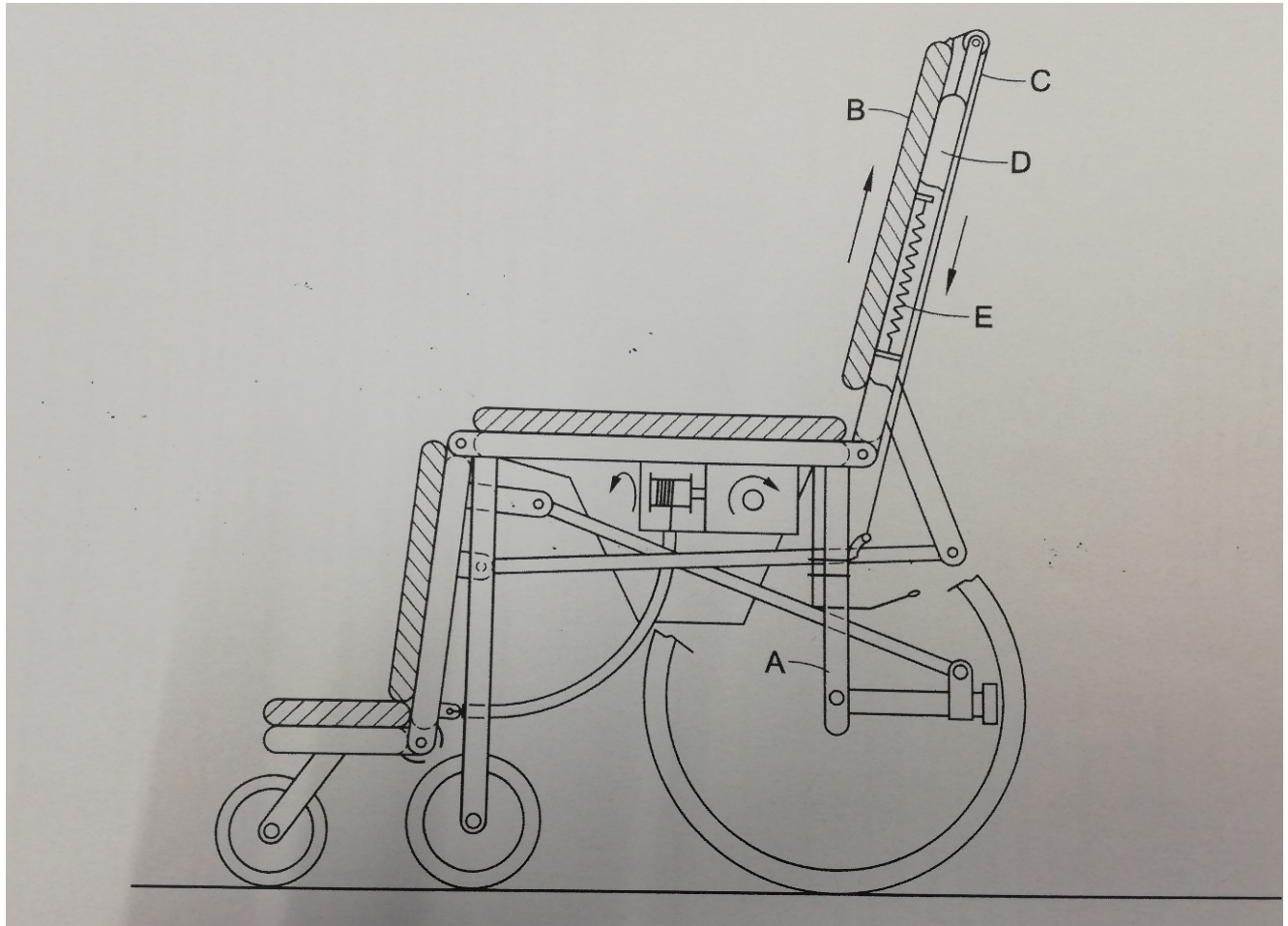


FIGURE 4.1: THE WHEELCHAIR IS IN THE SITTING POSITION

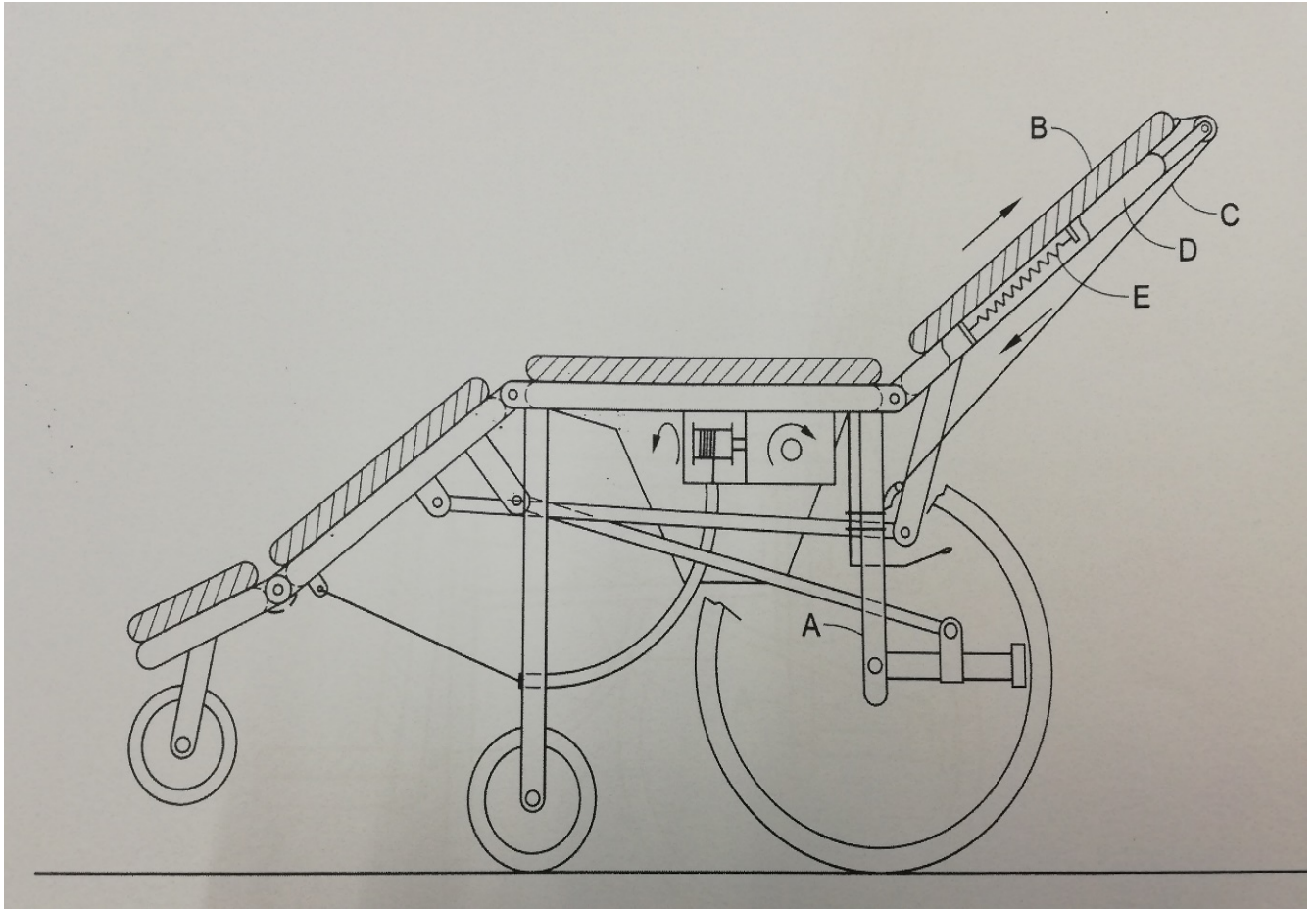


FIGURE 4.2: THE WHEELCHAIR IS IN THE RESTING POSITION

3.5 BUDGET CALCULATION

No	Materials / Equipment	Amount	Price
1.	Wheelchair body plates		RM150
2.	Front wheels	2	RM70
3.	Back wheels	2	RM150
4.	Arduino uno	1	RM25
5.	Power windows	2	RM200
6.	Motor driver	1	RM60
7.	Power supplier	1	RM60
8.	Hc-05 bluetooth connecter	1	RM20
9.	Jumper wires	2 sets	RM20
10.	Bidiversional switch	1	RM20
Total			RM775

TABLE 1.0

3.6 GANTT CHART

NO.		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1.	BRAINSTORMING	Yellow														
	-MEETING WITH LECTURER															
	-SMALL DISCUSSION WITH TEAM MEMBERS	Green	Green													
2.	- LISTING PARTS TO BUY		Yellow	Yellow												
	- BUYING PARTS FOR WHEELCHAIR		Green	Green												
3.	-BUILDING WHEELCHAIR BODY				Yellow	Yellow	Yellow									
	-INCLUDING BODY WELDING AND WHEEL WELDING				Green	Green	Green									
	- COMPLETING DECEPTION PART															
4.	- STUDYING ABOUT ARDUINO SYSTEM							Yellow	Yellow							
	- LISTING PARTS TO BUY FOR ARDUINO SYSTEM							Green	Green							
	BUYING ARDUINO SYSTEM PARTS															
5.	- CREATE AND TEST CODING FOR LED								Yellow	Yellow						
	-CREATE AND TEST CODING FOR DC MOTOR								Green	Green	Green	Green	Green			
	- TEST CODING FOR POWER WINDOW															
6.	ADJUST AND CREATE A SPACE FOR POWER										Yellow					

CHAPTER 4
FINDINGS AND ANALYSIS

4.1 The pie chart below shows the survey response from the patients itself.

The response are mainly from disabled patients.

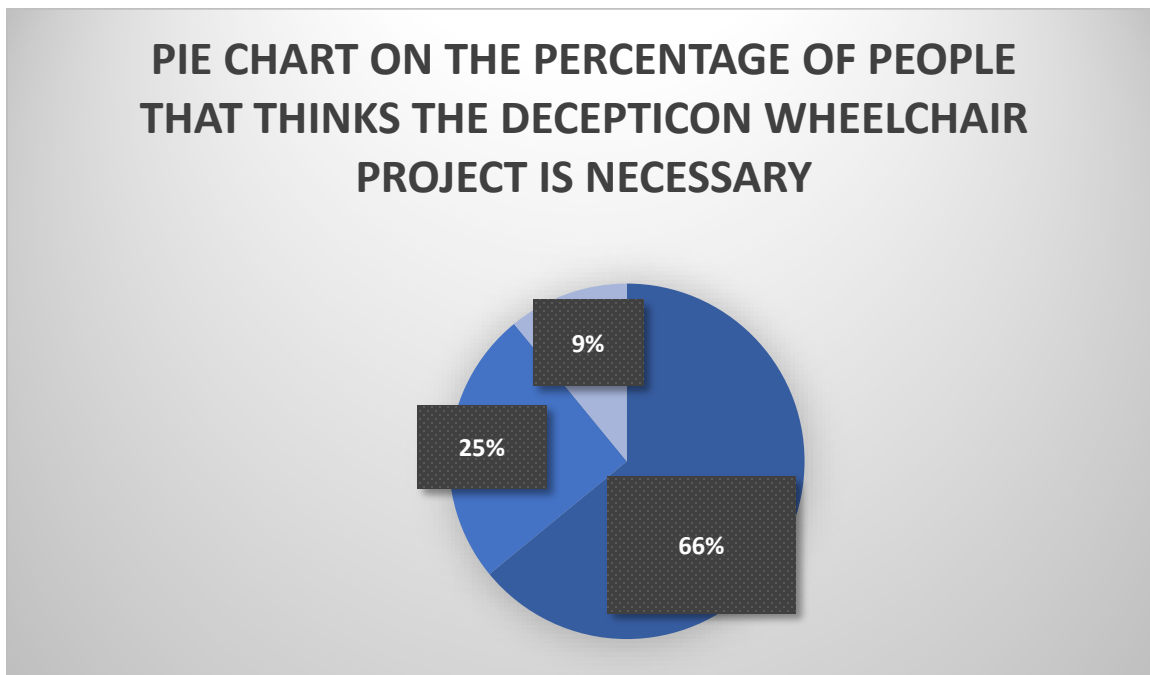
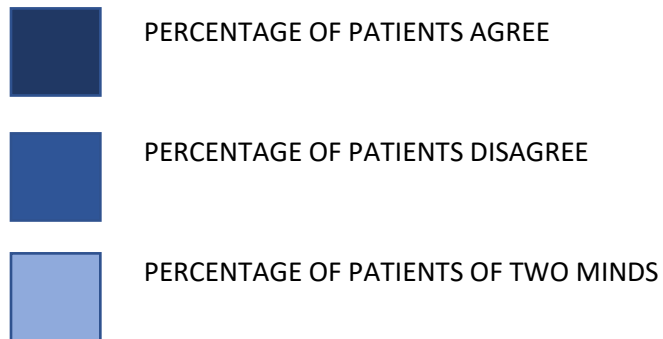


FIGURE 5.1



4.2 SURVEY

POLITEKNIK SULTAN SALAHUDDIN ABDUL AZIZ SHAH

INTRODUCTION

Greetings everyone, we the Diploma in Mechanical Engineering students from Polytechnic Shah Alam would like to conduct a survey on our mechanical project. Our project title is **SMART Wheelchair**. Our project is basically a wheelchair which can be just controlled by voice and smartphone and also can be convert into bed. Please spend a few minutes of your time to answer these few simple questions for our research purposes. Thank you in advance.

RESPONDENT INFORMATION

GENDER

AGE

1) Which type of wheelchair do you prefer?

Manually operated

Automatically operated

2) Does any of your family members / friends uses a wheelchair?

YES

NO

3) What type of illness/sickness are they facing?

4) Are they having difficulties in transferring from a wheelchair to a bed?

YES

NO

5) Do they need any assistant in order for them to transfer from the wheelchair to a bed?

YES

NO

6) How long do they usually take for the transferring process?

A few seconds

1-4 MINUTES

MORE THAN 5 MINUTES

7) Do you think that a convertible wheelchair to bed is necessary for them to make this transferring process?

YES

NO

8) Does operating a manual wheelchair makes them tired?

YES

NO

9) Do you face problems while helping them to push the wheelchair for a long time period?

YES

NO

10) Have you ever think want to find a better way to reduce your burden?

YES

NO

11) Do you agree that operating a wheelchair with voice and smartphone makes your or their work much more easy?

Agree

Disagree

12) Do you think using a smart wheelchair with low cost is reasonable?

YES

NO

4.3 Survey Conclusion

In conclusion, about 20 patients have given their responses towards our project and majority of them thinks that this smart wheelchair is necessary mainly in hospitals and believe that it would better their medical. There are patients whom disagree because this type of patients are used to moving without their disabled legs and hands and believe without their one hand or leg they can still able to climb on the bed and operate the manual wheelchair normally. The person helping the patient to push wheelchair are full agree with our project idea because they understand the burden while pushing the wheelchair with a load (human).

CHAPTER 5

DISCUSSION , CONCLUSION AND UPGRADE PLAN

Discussion

This smart wheelchair has created with a lot of specification and will be improved in future. These are the specifications:

Creativity

- This wheelchair can be adjusted into a deception wheelchair
- This wheelchair can be operated like controlling a remote car

Quality

- This wheelchair has been made with high quality steels
- It also has been made light weight steel and plates to make reduce it's weight
- This wheelchair has been added with good quality tyres to move freely

Adding Values(Nilai Tambah Produk)

- Arduino IDE software used to upload code to the arduino which use to control the system
- A HC-06 bluetooth connecter device used to connect the arduino system with smart phone
- A smartphone with arduino controlling app used to control the arduino system
- Two power window attached to the wheels with chain to control the mobility of wheelchair
- A Mega motor driver used to control the both power windows

FAEDAH/KEBAIKAN

Benefits of “Smart Wheelchair”

- This smart wheelchair can help the patient to move freely without caring about the weight
- This smart wheelchair can help the helper to push the wheelchair without wasting their energy.
- This smart wheelchair can be operate easily with just smartphone and no need extra operating tools.
- This smart wheelchair can avoid the backpain of the patient and elderly people because the sitting position can be adjusted.
- This smart wheelchair can help the patient to take rest because it can be change into a bed or deception wheelchair.

- This smart wheelchair can reduce the burden of elderly people in handling high technology system because it can be operated with voice command.
- It can avoid injuries because patients no need to be shifted from wheelchair to bed.

UPGRADE PLAN

The addition and upcoming features in our Smart wheelchair are :

1. The body of the wheelchair will be adjusted, so that it can be folded like a manual wheelchair.
2. An IR sensor will be place at the wheelchair to detect and avoid obstacles in the way
3. The wheelchair will be added with some safety features like seat belt
4. The speed and torque of the motor will be increased

CONCLUSION

So we can conclude that physically disabled and elderly people can move without any difficulty when use our smart wheelchair. They no need to be depend to other's help anymore to move from one to another place. They also no need to have any extra skills to operate this smart wheelchair because it can be operated just by voice command. This wheelchair also reduce the energy wasted by patient to operate the chair. Not only patient, This wheelchair also make the work of the helper(the person who push the wheelchair) much more easier. They just can handle the wheelchair with patient with just the smartphone in a particular distance. The patient also can change the wheelchair as a deception chair or bed anytime they want. Cost of such type of wheelchair will be affordable for all type of hospitals and it will be beneficial for patient handling. It is expected that this Smart Wheelchair would enable people's better medical and with the future recommendations of this project it would greatly reduce time and man-power to the old age home staff.

Not only that, we feel very happy throughout this project because we had made a good work with the guidance of our supervisor En. Muhammad Faiz bin Abdullah. We get a chance to implement our knowledge in welding, drilling and more throughout this project. We would like to pay our gratitude to our supervisor En. Muhammad Faiz bin Abdullah, to complete our project.

REFERENCES

- <https://patents.google.com/patent/US20100199422A1/en?q=WHEELCHAIR+WITH+A+COMMODE+THAT+CONVERTS+TO+BED&oq=WHEELCHAIR+WITH+A+COMMODE+THAT+CONVERTS+TO++BED>
- <https://www.seminaronly.com/Engineering-Projects/Mechanical/automatic-wheel-chair-cum-bed.php>
- <http://mechanical.srpec.org.in/files/Project/2015/15.pdf>
- <https://journalnx.com/papers/20150291-convertible-stretcher.PDF>
- <https://www.instructables.com/lesson/Controlling-Motor-Speed/>
- https://my.cytron.io/p-power-window-motor-with-coupling-left?r=1&qclid=CjwKCAjwg6b0BRBMEiwANd1_SGtdajUqGlzhqs7GX8A22UEa_s6OYDXGjTPuNmqa00V9P68cnm4vxoCPQYQAvD_BwE
- https://www.researchgate.net/figure/Powered-wheelchair-transformed-into-smart-wheelchair_fig1_322887169

THE END