



UNIVERSITI TEKNIKAL MALAYSIA MELAKA

**DESIGN AND DEVELOPMENT OF SMALL SIZE
REMOTE OPERATED VEHICLE (ROV).**

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Electrical Engineering Technology (Industrial Automation & Robotics) with Honours.

اونيورسي تيكنيكل مليسيا ملاك
by

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

AIMAN NASIRUDDIN BIN AMINUDIN

B071710387

960304-10-6153

FACULTY OF ELECTRICAL AND ELECTRONIC ENGINEERING

TECHNOLOGY

2020

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

Tajuk: DESIGN AND DEVELOPMENT OF SMALL SIZE REMOTE OPERATED VEHICLE (ROV).

Sesi Pengajian: 2019


Saya **AIMAN NASIRUDDIN BIN AMINUDIN** mengaku membenarkan Laporan PSM ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:


1. Laporan PSM adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan laporan PSM ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (X)

- SULIT* Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia sebagaimana yang termaktub dalam AKTA RAHSIA RASMI 1972.
- TERHAD* Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan.
- TIDAK TERHAD

Yang benar,

Disahkan oleh penyelia:


.....
AIMAN NASIRUDDIN BIN
AMINUDIN


.....
AMINURRASHID BIN NOORDIN

Alamat Tetap:

Cop Rasmi Penyelia

Lot 2991, Lrg. Idaman,

Sg. Lang Baru,

42700 Banting,

Selangor.

Tarikh: 15.2.2021

Tarikh: 17.2.2021

*Jika Laporan PSM ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan PSM ini

DECLARATION

I hereby, declared this report entitled DESIGN AND DEVELOPMENT OF SMALL SIZE REMOTE OPERATED VEHICLE (ROV). The results of my own research except as cited in references.



Signature:

Author: AIMAN NASIRUDDIN BIN
AMINUDIN

Date: 15.2.2021





اونيورسيتي تيكنيكل مليسيا ملاك

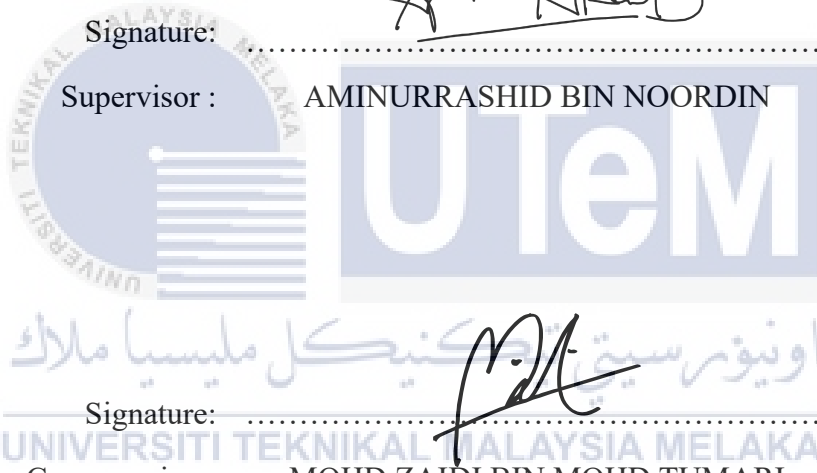
UNIVERSITI TEKNIKAL MALAYSIA MELAKA

APPROVAL

This report is submitted to the Faculty of Electrical and Electronic Engineering Technology of Universiti Teknikal Malaysia Melaka (UTeM) as a partial fulfilment of the requirements for the degree of Bachelor of Electrical Engineering Technology (Industrial Automation & Robotics) with Honours. The member of the supervisory is as follow:

Signature: 
Supervisor : AMINURRASHID BIN NOORDIN

Signature: 
Co-supervisor: MOHD ZAIDI BIN MOHD TUMARI



ABSTRAK

Remotely operated underwater vehicle (rov) merupakan robot yang mampu bergerak didalam air dan dikemudi dari darat, digunakan utk memantau kedalaman air laut. Berkomunikasi dan bertukar data melalui isyarat elektrik utk kawalan, penggunaan kabel wayar atau penambat menjadi pengantara antara rov dan pusat kawalan. Berkonsepkan rekaan saiz yang minimal dan senang dikawal, memudahkan utk beroperasi ketika di tapak operasi. Menjadi lebih manfaat apabila dapat menggantikan penyelam utk merentasi kawasan yang sempit dan sukar utk dilalui tambahan dengan kesuntukkan masa yang dihadapi oleh penyelam. Bagi mengenalkan kepada pelajar seluruh Malaysia tentang kecanggihan teknologi ini, satu pertandingan telah dilancarkan oleh pihak IIUM. Ini bertujuan membuka mata pelajar akan luasnya peluang kerjaya dalam bidang teknologi khususnya ROV dan dalam pada masa yang sama juga memberi sokongan kepada kejuruteraan maritim. Selain direka utk beroperasi di kawasan yang sempit, Ia juga direka utk membantu manusia melaksanakan misi yang berisiko tinggi didalam air. ROV untuk projek ini mestilah mempunyai saiz yang kecil dan struktur ROV ini direka menggunakan pengisian CAD 3 dimensi seterusnya dicetak menggunakan pencetak 3D dengan ketepatan millimeter. Brushless motor yang berskala kecil digunakan supaya ROV kelihatan kecil tambahan pula brushless motor ini mempunyai ciri yang ringan. Selain itu, brushless motor juga boleh mengawal kelajuan putaran motor yang dapat membuatkan ROV bergerak dengan lebih tepat. ROV ini juga mempunyai 6 darjah kebebasan pergerakan seperti surge, heave, sway, roll, pitch dan yaw. Dua sensor MPU9560 dan BMP180 ditambah bagi memudahkan ROV ini membuat pembaikan secara automasi. Sensor ini digunakan dalam mengukur altitude ROV dan kedalaman. Seterusnya, microcontroller esp32 yang menggunakan kernel FreeRTOS digunakan bagi mengabungkan semua data dan sensor dengan cekap dan tepat. Dalam pencapaian kajian ini, sebuah ROV yang bersaiz kecil dan mudah dikendalikan telah dibentuk. ROV ini telah mencapai prestasi yang baik untuk dari segi mekanisma penyedut digunakan untuk mengagkat dan letak guli. dalam masa 6 minit seperti yang dinyatakan di peraturan IRC2019. Akan tetapi, pengendali yang mahir sangat diperlukan untuk mengendalikan ROV dengan lancar.

ABSTRACT

A Remotely Operated Underwater Vehicle (ROV) is a highly maneuverable underwater robot that can be used to explore ocean depths while being operated by someone at the water surface. Use of cables, or tether, connects the ROV to the station, sending electrical signals to communicate and transmit data to control station or vice versa. There is also an ROV with a compact design and easy to use, that can be deployed immediately on the operation site. This is highly beneficial in emergencies where time is limited, and in areas that are too narrow or difficult to reach by divers. IIUM has made an event to bring together a student from all around Malaysia to introduce students to this fascinating technology so that they can explore career opportunities in this field. It also can support marine engineering early on through fun-filled activities. Therefore, ROV with a small body and mechanical part that can operate at tight space is developed to assist a human in performing a high-risk mission underwater. This project ROV is mainly created for a limited task, which is a pick and place a small object. The custom ROV structure is designed using 3d CAD and 3D printed with millimeter precision. Small brushless motor is used to keep the size small despite this motor characteristic is small and light. Brushless motor also has more control and constant of rotation speed that needed to move the ROV precisely. ROV has 6DOF of freedom movement consist of surge, heave, sway, roll, pitch and yaw. To add the auto correction feature in the ROV, 2 sensor is added. MPU9250 and BMP180 is used to measure attitude of ROV and Depth. For software controller, ESP32 that used FreeRTOS kernel is used to combine all the sensor and data together efficiently. In this project, a small size ROV that easy to control has been developed. This ROV have meet the best performance of sucker to pick and place a small marble within 6 minutes as clarify in IRC2019 rules. However, experience is the most importance to operate ROV effectively.

DEDICATION

With this thesis, my expression of special gratitude is for my family and friends. Also, to all people who support me. I am thankful and appreciate the motivation and constant for finishing this Bachelor Degree Project (BDP). I do not get to this stage without them.



ACKNOWLEDGEMENTS

Alhamdulillah, all praise to Allah in completing this project for the strength and His blessing. To Mr. Aminurrashid bin Noordin as my supervisor, I would give special thanks for all the supports, reviews, suggestions, and ideas for completing my Bachelor Degree Project (BDP).



TABLE OF CONTENTS

	PAGE
DECLARATION	iii
APPROVAL	iv
ABSTRAK	i
ABSTRACT	ii
DEDICATION	iii
ACKNOWLEDGEMENTS	iv
TABLE OF CONTENTS	v
LIST OF TABLES	vii
LIST OF FIGURES	viii
LIST OF APPENDICES	xii
LIST OF SYMBOLS	xiii
LIST OF ABBREVIATIONS	xiv
LIST OF PUBLICATIONS	xvi
CHAPTER 1 INTRODUCTION	1
1.1 Background	1
1.2 Problem Statement	2
1.3 Objective	3
1.4 Scope	3
CHAPTER 2 LITERATURE REVIEW	4
2.1 Introduction	4
2.2 Mini Design of ROV	4
2.3 Pick and Place Mechanism in Underwater Purpose.	7
2.4 Underwater Wireless Communication.	9
2.5 IMU Sensor and Control Component System for Underwater.	10
2.6 Previous Work	15
2.6.1 A Small Scale ROV For Shallow-Water Science Operation	15
CHAPTER 3 PROJECT METHODOLOGY	20

3.1	Introduction	20
3.2	First Milestone (Literature Review)	21
3.3	Second Milestone (Mechanical Hardware Design)	22
	3.3.1 Propeller Design	22
	3.3.2 Motor Mount Design	23
	3.3.3 Sucker Mechanism Design	24
	3.3.4 Body Assembly Design	25
3.4	Third Milestone (Electrical Hardware Design)	27
	3.4.1 ESP32 Microcontroller	27
	3.4.2 Brushless Motor.	28
	3.4.3 BLHeli ESC	29
	3.4.4 MPU9250	31
	3.4.5 BMP180	31
	3.4.6 Lithium Polymer Battery	32
	3.4.7 Radio Control.	33
3.5	Fourth Milestone (Assembly and Integration)	34
	3.5.1 Schematics Design of Overall component.	37
	3.5.2 Control Schematic of ROV	38
3.6	Fifth Milestone	38
	3.6.1 Testing and Analysis of the ROV Motor Vector Algorithm.	38
	3.6.2 Testing and Analysis of the ROV Hovering System.	40
	3.6.3 Analyse the Performance of ROV to Run Pick and Place Task.	40
3.7	Summary	41
CHAPTER 4 RESULTS AND DISCUSSION		42
4.1	Introduction	42
4.2	Designing the Depth Sensor.	42
4.3	Analysis of Axis Stability	45
	4.3.1 Roll Axis Control	45
	4.3.2 Pitch Axis Control	46
	4.3.3 Yaw Axis Control	46
	4.3.4 Depth Control	47
4.4	Analysis of Moving Stability.	48
	4.4.1 Move Forward	48
	4.4.2 Move Backward	49
	4.4.3 Move Sideway (Left)	50
	4.4.4 Move Sideway (Right)	51
4.5	Designing and Analysis of the Sucker Mechanism	52
4.6	Analysis to complete Task	53
CHAPTER 5 CONCLUSION		54
5.1	Introduction	54
5.2	Conclusion.	54
5.3	Recommendation and Future Improvement	55
REFERENCES		57
APPENDIX		59

LIST OF TABLES

TABLE	TITLE	PAGE
Table 2.1:	The parameters of some commercial ROV's	5
Table 2.2:	Specifications of candidate thrusters	6



LIST OF FIGURES

FIGURE	TITLE	PAGE
Figure 2.1:	Mini ROV operated underwater.	4
Figure 2.2:	The general arrangement of UWTV and CU-ROV.	6
Figure 2.3:	Thruster options with three types of propeller blades.	6
Figure 2.4:	Thruster performance obtained from the experiments.	7
Figure 2.5:	Effects of current o ROV Mounted with a manipulator.	8
Figure 2.6:	The complete manipulator arm with actuator units.	9
Figure 2.7:	Target applications of TDD-USAAN system.	10
Figure 2.8:	Single IMU Integration.	11
Figure 2.9:	Multiple INS Configuration.	12
Figure 2.10:	The PID controller was implemented for the ROV system.	14
Figure 2.11:	Inside sensor box.	14
Figure 2.12:	Beneficial of ROVs.	15
Figure 2.13:	Overall, Tessie System.	16
Figure 2.14:	Tessie vehicle with key components.	17
Figure 2.15:	Control box.	17
Figure 2.16:	Block diagram of the system.	18

Figure 2.17: PID heading control results. A series of disturbances were introduced to observe control response, at times $t = 17$ sec, 19 sec, 22 sec, 28 sec, and 32 sec.	19
Figure 2.18: Review of handling.	19
Figure 3.1: Methodology flowchart.	20
Figure 3.2: First Milestone flow chart.	21
Figure 3.3: Propeller design	22
Figure 3.4: Propeller printed and ready to use	22
Figure 3.5: Motor mount	23
Figure 3.6: Motor mount (Grey) with rotor (Blue) in place.	23
Figure 3.7: Top view motor mount (Grey) with rotor (Blue) in place.	24
Figure 3.8: Sucker mechanism	24
Figure 3.9: ROV full assembly design	25
Figure 3.10: ROV design side view	26
Figure 3.11: ROV design bottom view	26
Figure 3.12: ROV open compartment mechanism.	26
Figure 3.13: ESP32 Board	27
Figure 3.14: ESP32 pinouts (Components101 2020).	28
Figure 3.15: SB1605 Brushless Motor.	29
Figure 3.16: Mini BLHeli ESC 20A	30
Figure 3.17: The user interface of BLHeli Suite software	30
Figure 3.18: MPU 9250 module.	31

Figure 3.19: BMP180 Module	32
Figure 3.20: Example of Lithium Polymer Battery (Schneider, 2019).	33
Figure 3.21: Lithium Battery that will be used.	33
Figure 3.22: Fly Sky i6, transmitter overview.	34
Figure 3.23: flow chart of part assembly and integration.	35
Figure 3.24: Overall ROV view	36
Figure 3.25: Schematic design of the overall electronic component.	37
Figure 3.26: Block diagram of ROV control system.	38
Figure 3.27: Flowchart of testing the motor vector algorithm.	39
Figure 3.28: 6 degree of freedom movement.	39
Figure 3.29: Flowchart of testing the hovering System.	40
Figure 3.30: Flowchart of testing the performance of ROV to complete the task.	41
Figure 4.1: depth sensor design principal.	43
Figure 4.2: BMP180 sensor covered by a layer of foam	43
Figure 4.3: BPM180 inside a plastic cylinder.	43
Figure 4.4: Reading of BMP180 underwater.	44
Figure 4.5: Graph roll angle vs time	45
Figure 4.6: Graph pitch angle vs time	46
Figure 4.7: Graph yaw angle vs time	46
Figure 4.8: Graph depth vs time	47
Figure 4.9: Graph of controller response during moving forward.	48

Figure 4.10: Graph of controller response during moving backward.	49
Figure 4.11: Graph of controller response during moving left sideway.	50
Figure 4.12: Graph of controller response during moving right sideway.	51
Figure 4.13: Graph, distance sucker from object vs time taken to lift it.	52
Figure 4.14: Bar graph of score gain vs pilot experience	53

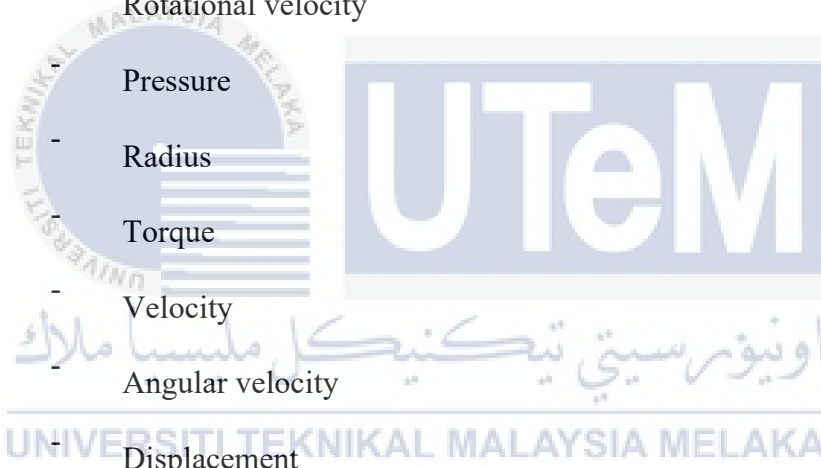


LIST OF APPENDICES

APPENDIX	TITLE	PAGE
Appendix i	a Gantt Chart	59
Appendix ii	: Code “MiniSubV2.ino”	59
Appendix iii	: Code “0_BMP180.ino”	63
Appendix iv	: Code “0_MPU9250.ino”	65
Appendix v	: Code “0_OTA_Update.ino”	70
Appendix vi	: Code “0_ProcessControl.ino”	73
Appendix vii	: Code “0_Receiver.ino”.	79
Appendix viii	: Code “0_SerialProcess”.	82
Appendix ix	: Code “0_Servo”.	86
Appendix x	: Code “0_TelnetSerial”.	89
Appendix xi	: Code “0_LED_blink”.	92

LIST OF SYMBOLS

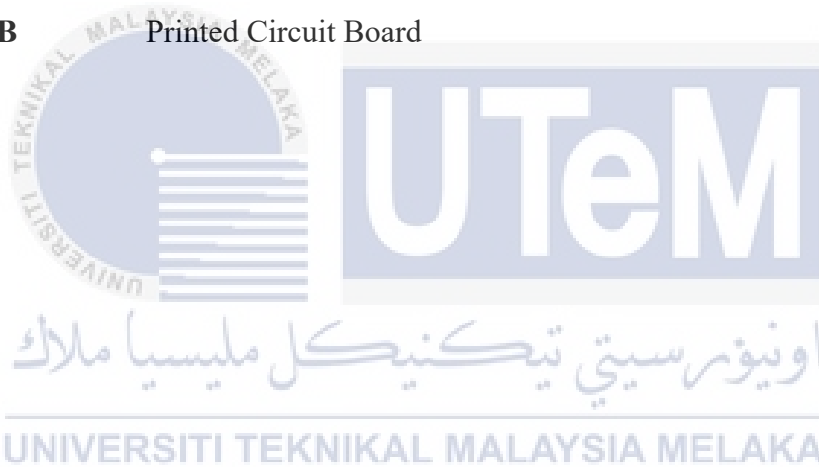
D, d	-	Diameter
F	-	Force
g	-	Gravity = 9.81 m/s
I	-	Moment of inertia
l	-	Length
m	-	Mass
N	-	Rotational velocity
P	-	Pressure
r	-	Radius
T	-	Torque
V	-	Velocity
w	-	Angular velocity
x	-	Displacement
z	-	Height
q	-	Angle
Hz	-	Hertz
Kv	-	RPM of the motor per volt
rpm	-	Rotation per minutes



LIST OF ABBREVIATIONS

ROV	Remote Operated Vehicle.
ADC	Analog Digital Conversion.
ESC	Electronic Speed Controller.
PWM	Pulse Width Modulator.
AFHDS	Automatic Frequency Hopping Digital System
PLA	Polylactic acid
CB	Center of Buoyancy
CG	Center of Gravity
USB	Universal Serial Bus
DOF	Degree of Freedom
UWTV	Under Water TV System
AUV	Autonomous Underwater Vehicles
MAC	Media Access Control
TDD	Time Division Duplex
USAAN	Underwater Small Area Acoustic Network
OFDM	Orthogonal Frequency Division Multiplexing
IMU	Inertial Measuring Unit
GPS	Global Positioning System
MEMS	Micro Electro-Mechanical System
PID	Proportional Integral Derivatives
ABS	Acrylonitrile Butadiene Styrene

TCP	Transmission Control Protocol
IP	Internet Protocol
SPI	Serial Peripheral Interface
PWM	Pulse Width Modulation
TDD	Time Division Duplex
UART	Universal Asynchronous Receiver-transmitter
RPM	Revolution Per Minute
GUI	Graphical User Interface
PCB	Printed Circuit Board



LIST OF PUBLICATIONS



CHAPTER 1

INTRODUCTION

1.1 Background

In the present era, Remotely Operated Vehicle (ROV) widely used across many industry sectors. A single operator or driver must use this type of Underwater Vehicle (UV). This UV can also save human life compared to conventional methods that require humans to dive into conducting research, making observations, or performing an underwater task (Azis et al. 2012). The human body can withstand diving to a depth of up to 30 m before the toxic reaction within the body starts to react. Hence, to overcome this limitation, for the exploration of underwater locations deeper than 30 m without endangering its driver, the ROV can be utilized. The concern with the new ROV working class is that they are expensive because they cost more than RM 200,000 (Aras et al. 2015). A smaller-scale ROV with the cheaper price are needed for research and study purposes. The ROV of small scale must have the same behavior as the ROV of industry class. Also, this concept ROV has autonomous depth control, which does not vary from the ROV used for monitoring of underwater pipelines.

The motivation of this projects is based on the previous competition IIUM Robotic Competition 2019 (IRC2019) that take place in the International Cultural Centre (ICC), International Islamic University Malaysia (IIUM). This event was joined by a student from FTKEE robotic Club (HERO) under category Remotely Operated Underwater Vehicle (ROV). This team developed a simple ROV prototype to complete the competition task and manage to be a champion due to maintenance of the ROV by teammates and consistency of

running the ROV without fail. Each successful round collects the score that able for the team to continue to the final round. However, during that event, a few weaknesses have been found by the team. The ROV did not have much torque and speed compare than the other competitor, and the manipulator mechanism that use griper method is hard to use. The ROV needs to reach the object closely to make it able to grab. Therefore, a better manipulator mechanism, higher torque motor and improved movement degree of freedom (DOF) control design need to develop for better performance ROV.

1.2 Problem Statement

From the previous competition, the IRC2019 at IIUM held in September 2019, there are several modifications that can be made to enhance the capabilities of the first ROV prototype. Even the required tasks can be performed, and it was still difficult to control ROV stability to get the highest marks within 6 minutes. The movement is very sluggish and hard to control. Additionally, high body rotational error and displacement error has occurred. This error causes high water flow interference because of prop washes in tight spaces and unbalanced thrust from each propeller. Therefore, this project aims to design and develop a better manipulator mechanism, higher torque motor and improved movement degree of freedom (DOF) control design.

1.3 Objective

The objectives of this project are as follows:

- i. To develop a functional Remote Operated Vehicle (ROV) with a small scale.
- ii. To apply sensor fusion to stabilize the ROV during hover at a specific depth.
- iii. To analyse the ROV performances to complete a mission as regulated in IRC 2019 competition rules.

1.4 Scope

Several requirements are suggested by narrowing the expectations for this project to ensure that this project accomplishes its objectives. For this project, the scopes covered are:

- i. A design of ROV structure is used up to a total of 6 brushless motors for omnidirectional force motor position.
- ii. Design of a sucker system to pick and place a small sphere marble.
- iii. A design of with ROV with overall maximum dimension of 30cm (width) x 30cm (length) x 30cm (height).
- iv. An IMU sensor consists of 3-axis gyroscope, 3-axis accelerometer and 3axis magnetometer is used to control ROV attitude stabilization
- v. A barometric sensor is used to control ROV depth and to hover while performing a task.
- vi. A 10 degree of freedom (DOF) sensor fusion technique have been applied for sensing the movement of ROV respective to its environment.
- vii. Analyse the stability of ROV attitude and altitude control.
- viii. Analyse the performance of sucker to pick and place a small marble within 6 minutes as IRC2019 rules.