DESIGN AND DEVELOPMENT OF DIRECTIONAL CAMERA MECHANISM FOR REMOTELY PILOTED AIRSHIP SYSTEM

by

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ABSTRACT

As an important way to obtain the high-resolution remote sensing images, the unmanned aerial vehicle (UAV) play an important role in the area of photogrammetry and remote sensing application. This purpose of this study are to develop the camera platform for remote sensing. The remote sensing are used to monitoring wildlife at Malaysia's rainforest. The development of camera platform will be used on an Airship. Besides, the camera platform are design based on monitoring requirement. When designing the camera platform the objectives are used as guidelines. Started from preliminary design, then the design are optimized to fulfill the objectives. Finally, optimized design are compared with design in previous studied.

REKABENTUK DAN PEMBANGUNAN MEKANISMA PENGHALAAN KAMERA UNTUK SISTEM BELON UDARA KAWALAN JAUH

ABSTRAK

Sebagai satu cara yang penting untuk mendapatkan imej resolusi tinggi dari jarak jauh, kenderaan udara tanpa pemandu (UAV) memainkan peranan penting dalam bidang fotogrametri dan aplikasi pengawasan jauh. Tujuan kajian ini adalah untuk membangunkan platform kamera untuk pengawasan jauh. Pengawasan jauh digunakan untuk pemantauan hidupan liar di hutan hujan Malaysia. Pembangunan platform kamera akan digunakan pada Belon Udara. Selain itu, Rekabentuk platform kamera adalah berdasarkan keperluan pemantauan. Dalam prosess rekabentuk, objektif dijadikan petunjuk untuk rekabentuk pemegang kamera. Dimulakan dengan rekabentuk permulaan, kemudian rekabentuk tersebut dioptimasikan untuk memenuhi kehendak objektif. Akhir sekali, rekabentuk yang telah dioptimasi akan dibandingkan dengan rekabentuk yang telah dibuat sebelum ini.

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DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

NUR NASRIQ ELLANIE BIN SAILAN
Date:

STATEMENT 1

This thesis is the result of my own investigations, except where otherwise stated. Other sources are acknowledged by giving explicit references. Bibliography/references are appended.

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STATEMENT 2

I hereby give consent for my thesis, if accepted, to be available for photocopying and for interlibrary loan, and for the title and summary to be made available to outside organizations.

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LIST OF ABBREVIATIONS

UAV	Unmanned Aerial Vehicle
DOF	Degree-of-Freedom

CHAPTER 1

INTRODUCTION

1.1 General overview

Remote sensing application for agriculture and forestry often require images with a high temporal resolution. This is difficult or costly to obtain either by satellite imagery or conventional airborne data. Therefore, unmanned drones or unmanned aerial vehicle (UAV) is develop to monitor the forestry. But current civilian and affordable UAV are still not be able to fulfil the listed requirement because there are several major problems with the previous UAV monitoring system. As an example, no vertical adjustment for the aerial camera which results in tilted pictures cause by wind or instability of the platform.

The development of this directional camera are to be used for airship monitoring system. Mechanical design for 2-degree of freedom mechanism that control the camera will have a damper that will reduce the vibration thus the monitoring can be seen more clearly. Analysis are made to the structure. Then the design will be compared to another previous design. It will be compared to its design and weight. Then conclusion are made based on the analysis.

1.2 Problem Statement

Practically all of the wildlife in Malaysia's forests are under threat from human activities and unless action is taken to protect these areas. In the future, it is likely that many remarkable animals will no longer be found in Malaysia. In addition to this, Malaysia's forests provide the water that we drink, we use to grow our food and also support many industries. Without healthy forests and the ecosystem services they provide, the success and stability of Malaysian society is also at risk. Wildlife monitoring is essential for keeping track of animal movement patterns, habitat utilisation, population demographics, snaring and poaching incidents and breakouts. For this project, UAV will be used to monitoring the wildlife.

Imaging, sensors, and application are the fundamental units of image acquisition devices and equipment which convert the real world image into digital signals. The airship is used to monitoring wildlife. Monitoring system that available right now which is using UAV or quadcopter can't fulfil the best requirement needed for monitoring. Because of the UAV speed, the animal can't be observed in detail. While using of airship is good because of the speed. And the use of directional camera is to get the accurate estimate species abundance.

1.3 Objectives

The main objective for this project are to design and develop directional camera for a remotely piloted airship system. And the design should fulfill other several objectives.

The design objectives for this project are:

1. Self-balancing when nadir pointing.
2. Lightweight structure.

1.4 Scope of Work

The scope of work for this study focus on the design and development of 2-DOF camera mechanism that can be use on airship hence improve the wildlife monitoring. To calculate and design based on input parameter that are crucial to this project objectives. The design should not exceed the parameter allowed and the most crucial one is weight of the mechanism.

1.5 Dissertation Outline

This dissertation contains five chapters:

Chapter 1 discusses more on the background, problem statement, objectives and scope of this study. It gives an overview for the study.

Chapter 2 explains the literature reviews related to this work. The focus is on previous design of wildlife monitoring UAV and their camera system.

Chapter 3 covers the methodology and technique used in this research. It includes list of software use, preliminary design, and mechanical design.

Chapter 4 presents the results obtained from the preliminary design and development. The results are presented in graphical form and analysis and discussion are made in detail.

Chapter 5 concludes the findings of the research and provide recommendations for improvement in future studies.

CHAPTER 2

LITERATURE REVIEW

The available 3-axis camera controller is using electronic gimbal system. Gimbal system is a pivoted support that allows the rotation of an object about a single axis. Electronic gimbal system is popular in cameraman that shooting video or picture when he is moving because it's stabilize the camera shake and vibration. It usually driven by three servos or brushless motor. The electronic gimbal have the ability to keep the camera level on all axes as it moves, with very rapid responses. But all the available camera control using gimbal can't control the camera direction to the point we want. It only can be setup initially which direction the camera to be focused and stabilized. For this airship's system we want the camera can be control using Remote Controller (RC) based on the observation of wildlife. Basically this project want to develop the basic function of available camera control system with an advance control element. Thus the development of this directional camera is important to fulfil the requirement of the airship mission.

The increase in availability of inexpensive Unmanned Aerial Vehicles (UAVs) provides an opportunity for wildlife experts to use an aerial sensor platform to monitor wildlife and tackle many of these challenges to accurately estimate species abundance. In recent years, the use of UAVs that can perform flight paths autonomously and acquire geo-referenced sensor data has increased sharply for agricultural, environmental and wildlife monitoring applications. Some issues restricting the wider use of UAVs for wildlife management and research include UAV regulations operational costs and public perception. One of the most important restrictions, however, is the need to develop or apply automated camera controller.

2.1 Remote Sensing Platform

In the past, majority of remote sensing applications in agriculture were either satellite- or ground-based. Over the last few years we have seen a rapid increase in airborne remote sensing due to the proliferation of multispectral digital airborne sensors.

Table 2.1 gives an overview of the different remote sensing platforms with the typical spatial resolution of their multispectral channels and with their typical fields-of-view (FOV). This overview illustrates the current resolution gap at the cm to dm level which could ideally be filled by miniature UAVs.

Table 2.1: Remote Sensing Platform

Remote Sensing Platform	Typical Spatial Resolution	Typical Field-of-View (FOV)
Satellite	2-15 m	10-50 km
Aircraft (piloted)	0.2-2 m	2-5 km
Miniature UAV	1-20 cm	50-500 m
Ground-based	< 1 cm	< 2 m

2.2 Unmanned Aerial Vehicle (UAV) as Platform

Over the last few years we have seen a tremendous development of UAV technologies at all conceivable sizes, from business jet sized UAVs right down to artificial 'flying insects'. There is also an increasing number of projects with the aim of using UAVs for remote sensing purposes. These UAV platforms for civilian remote sensing purposes range from large UAVs (Coronado et al., 2003), (Herwitz et al., 2002) through mini UAVs (Johnson et al., 2003), (Eisenbeiss, 2004), (Annen et al., 2007) to micro UAVs presented in Table 2.2

Table 2.2: UAV Category

Category	Max Take-Off Weight	Max Flight Altitude	Endurance
Micro	< 5kg	250m	1h
Mini	< 30kg	150-300m	< 2h

Due to the rapid development and the ever increasing number of new UAV concepts and technologies, it has become a necessity to try and establish a certain classification for UAVs. The European Association of Unmanned Vehicle Systems (EUROUVS) has drawn up such classification of UAV systems, which adhere to in this paper. A good overview and state-of-the-art of UAV systems which is based on the EUROUVS classification can be found in (Bento, 2008).

The use of mini or micro UAVs for remote sensing purposes introduces a number of constraints on the imaging payloads, namely limitations in terms of weight, power, and space. In case of micro UAVs there are also very limited possibilities for payload stabilisation or for the highly accurate direct sensor geo referencing. Typical weight limitations for imaging payloads are approx. 20-30% of total weight of the system, e.g. approximately 300g in case of 1kg micro UAVs and around 5kg in case of 25-30 kg mini UAVs. Overall, UAV have proven to be effective at carrying out wild life monitoring surveys. However in many cases, the extensive post-processing effort required negates any convenience or time savings afforded by UAVs in the field compared to conventional survey methods

Airship has been used since decades ago as a flight platform. The major use of the airship back then was for surveillance also as a bomb-dropping device. Previous studies have shown that, there are hundreds of applications that use UAVs such as quadcopter, drone or even a small size aircraft for specific purposes. In this sense, the airship is the most suitable aerial vehicle to be used as monitoring system because the normal airship, the fastest it can fly is about 50 km/h against the wind which is quite slow. Moreover, the airfoil-shaped airship is designed in order to improve the buoyancy, the upward force, and lift. The lift gained from the envelope which is filled with Helium gas, a lifting gas that is less dense than the surrounding air. In the in early 1900s the Hydrogen gas was used before it was completely banned due to some incidences due to the lifting gas thus the people back then switched to using Helium gas because it is not flammable making it a safer alternative than Hydrogen. For this project, the camera controller design will be used on an airship. This is the first time that airship will be used to monitoring wildlife. Thus the camera controller design is different from previous UAV platform.

2.3 Camera Platform

In previous studied, the application of two independent cameras in one suspension system is one of the key features of the system [Margarita.U *et al.*, 2014]. The navigation camera of the front view is intended for piloting the aerial vehicle. This is a fixed camera sending realtime images to the ground-based cockpit. With the help of the navigation camera, it is possible not only to control the system but also to carry out monitoring and detect targets. The second camera – a high-resolution rotating camera placed in the suspension – is intended for photographing and video filming. If the system is controlled by one operator, it is possible to switch the AV to the automatic flight mode with the help of the navigation camera when the target is detected, for example, to circle with a certain radius while the operator uses the surveillance equipment to film/photograph the target. If the system is controlled by two operators, the efficiency of monitoring increases substantially. The UAV operator pilots the system in cooperation with an operator of photo and video equipment; thus, the area of observation is extended, and the speed of target detection and processing increases. Figure 2.1 show the UAV features.

Figure 2-1: UAV Features

The UAV fuselage has a shape that complies with the requirements of reduced aerodynamic drag and contains power batteries in a special compartment as well as control system and navigation elements. All disposable loads are placed in a special nacelle, which is hung at the bottom of the fuselage and has a shape providing reduced aerodynamic drag. Optimum size and shape of the platform were chosen with account of overall dimensions of the equipment to be installed. As the camera rotates along the lateral axis, the platform must correspondingly have a cylindrical shape. The platform can also rotate inside the cylindrical casing (skin). However, the choice was made in favour of the first variant because in this case the camera was better protected. The design shown in Figure 2.2

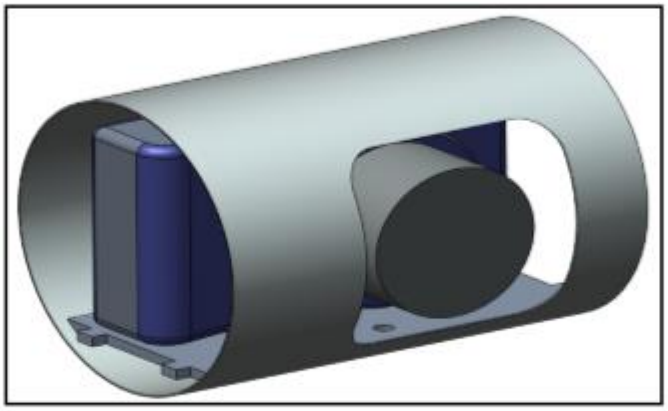

Figure 2-2: Camera Platform (Margarita.U *et al*., 2014)

Special attention was devoted to the creation of the mechanism itself. Rotation of such a structure cannot be implemented directly from the power drive because the rotation axis has a hole, where the wires are placed. Therefore, it was necessary to design a reduction unit, which would transmit the drive from the servo drive with the help of gears. Taking into account a limited rotation ability of the servo drive within the range of 120º, at the first stage it was decided to make a multiplier with a transmitting angle of 2:1 that would increase the angle of camera rotation up to 240º. Glass fiber plastic was chosen as the most suitable material for manufacturing gears and clamping frames from the point of view of strength and ease of processing. When all the parts were manufactured, full-scale tests of the mechanism performance were carried out. Rotation was implemented at high turning speed with periodical sticking. The tests revealed the inadequate quality of manufacturing of parts and insufficient power of the servo drive that made it impossible to exceed the moment of the multiplier. It was unacceptable to use a more powerful servo drive because it would increase the weight of the whole structure, therefore it was decided to re-equip the servo drive by turning it into a constant rotation drive. The required result was achieved after the rearrangement of internal servo components. The camera rotation mechanism has a constant rotation servo drive that makes it possible to rotate the camera at any angle; the wiring of electronic devices passes through a special tube in the centre of the frame in order not to hinder the rotation of the middle part of the nacelle containing the surveillance equipment. External loads are transmitted to a special shaft and not directly to the servo drive, which provides the reliability of the structure.

In another studied, a sensor gimbal is developed that features compact size, light weight, and a 2-axis drive capability [Wada.A *et al.*, 2012]. Figure 2.3 shows an external view and the internal structure of the gimbal and table 2.2 shows its main specification.

Figure 2-3 External view and internal structure of the sensor gimbal (Wada.A *et al*., 2012)

Table 2.2: Specification

Item		Specifications	
Material		Aluminum	
Weight		Approx. 600 g (including mounted sensor)	
Gimbal drive angles		AZ: ±95° EL: +90° to -20°	
Dimensions		130D × 130H mm	
Mounted sensors		Visible-light camera	IR camera (NEC)
	Video output	NTSC	NTSC/PAL
	Pixels	380,000 pixels	320(H) × 240(V)
	Weight	Approx. 50 grams	Approx. 150 grams
	Dimensions	25W × 25H × 28.5D mm	38W × 38H × 65D mm

The developed sensor gimbal introduces sheet metal for the internal frame in order to reduce the weight but adopts a unique integrated architecture that combines the frame with an aluminum semi-spherical dome to ensure adequate mechanical rigidity. In addition, an IR transmission insulation protection cover (a commercially available product) is fitted that are capable of providing protection from far-infrared (IR) rays as well as visible-light electro-optical (EO) rays, in order to integrate the camera window section and reduce weight.

While achieving an overall weight of about 600 grams by reducing the weight of component parts and adopting a compact, lightweight motor, the sensor gimbal still implements sufficient drive performance characteristics to enable the satisfactory flight of the UAV. The IR sensor mounted on the gimbal is an uncooled IR sensor for wavelengths of from 8 to 14 μm. This has been developed independently by us. Mounting it in combination with the visible-light sensor enables information collection even at night or against smoke.

2.4 Type of Camera Used

Camera takes important roles in remote sensing because it is the main part used to sensing. The camera used is based on the objectives of the wildlife monitoring. There are several types of camera that commonly used to monitoring wildlife.

- High resolution camera
- Thermal imaging camera

- Multispectral and hyperspectral imaging

2.4.1 High resolution camera

This camera basically intended for photographing and video filming. And also to carry out monitoring and detects target. There are an increasing number of light-weight imaging sensors for the visible spectrum and for thermal infrared, the situation is completely different in the case of multispectral sensors. In the case of imaging sensors for the visible spectrum, there is now a wide range of lightweight consumer cameras with weights of 150g or even less and with up to 10 MPixels or more. Unfortunately, these sensors also come with a number of features which have adverse effects on photogrammetric or remote sensing applications. These include limited optical quality, mostly zoom lenses, fully automatic focusing and image stabilization which make the task of camera calibration very difficult. There are a number of operators providing remote sensing services for agriculture based on RGB imagery only. While this kind of imagery might provide valuable visual information to farmers, it is certainly not suitable to analytically assess vegetation properties due to the lack of information in the NIR band.

2.4.2 Thermal imaging camera

Thermal imaging mainly used to monitor wildlife at night. There are several species that only active at night, at this point come the importance of thermal imaging because we can't detect the animal with the normal high resolutions camera at night. And if we used light to pair with high resolutions camera, the animals will get scared and hide. That's why thermal imaging is used at night. There has been a tremendous progress in the field of miniature thermal imaging sensors over the last few years resulting in commercially available thermal imaging sensors with weights in the order of 120g. As an example, the FLIR camera Tau 2-640. The camera weighs 100 g and has a 640x480 pixels resolution and 25 mm focal lens. The FLIR has a field of view of 25ˆ22 degrees.

2.4.3 Multispectral and Hyperspectral camera

The development of sensors for acquiring high-quality, co-registered multi-channel imagery in the visible and in the Near Infrared (NIR) bands poses a number of challenges in terms of optics, sensors, sensor control and calibration. In their recent overview on airborne digital imaging technologies (Petrie & Walker, 2007) identify four different concepts for producing multi-channel imagery with small-format airborne digital cameras. Among them are single lens solutions with specialized mosaic filters, multiple arrays, or beam splitters or with solutions based on multiple cameras. Among the lightest multispectral camera systems available are the DigiCAM-H39 (IGI, 2007) with a CIR option and a total weight of approx. 5 kg and Tetracam's recently released Multichannel Camera MCA4 with approx. 1.8 kg and ADC2 with approx. 500 g. The latter sensor appears promising for operations on mini or even micro UAV, however, the quoted interval of 12 seconds between two individual images would only permit stationary image acquisition.

Noteworthy investigations by (Rufino and Moccia, 2005) or (Johnson et al., 2003) create a hyperspectral line sensor by combining a monochromatic camera with a spectrograph and attempt to use it on UAVs. However, it remains questionable, if and how such line sensors can satisfactorily be used on mini or micro UAVs with their relative low attitude determination capability and the lack of payload stabilisation.

CHAPTER 3

METHODOLOGY

3.1 Overview

Design work were majorly done in this study using CATIA V5 software to design the part of the camera mechanism virtually before analysis were done. The design method divided to two design process which is preliminary design and mechanical design.

In preliminary design process, the process started with sketching the overall idea for the mechanism at an A4 paper. Then the two of the best design is selected and selected design were dissembled to a several parts.

After the preliminary design the mechanical design were done on the CATIA V5. The mechanical design drawn by part and then were assemble. Afterward the design is drawn in technical drawing. In this stage, component for the mechanism were selected based on the design satisfactory. The overall methodology of the research is summarized in Figure 3.1.

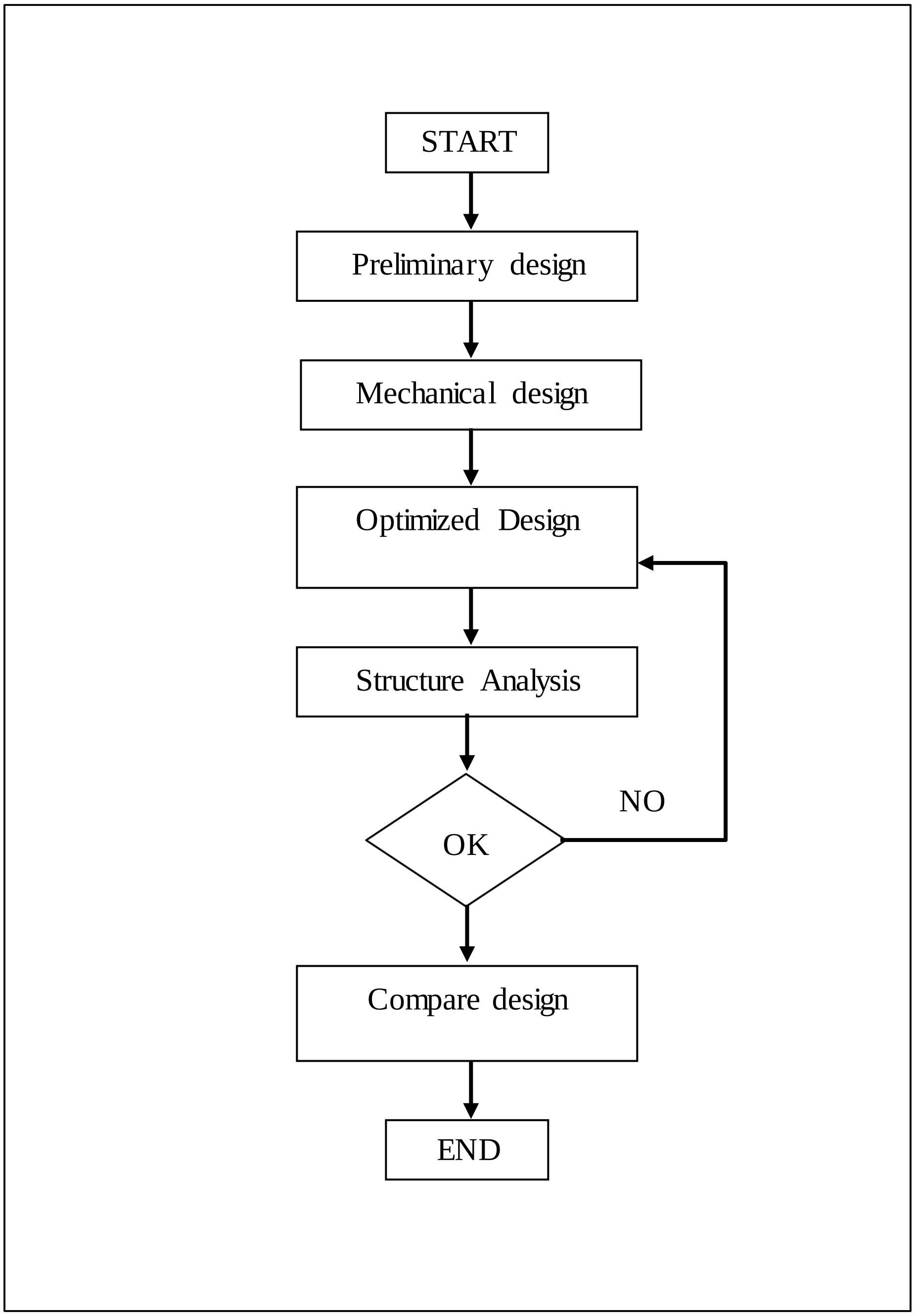

Figure 3-1 : Flow Chart of Methodology

3.2 List of software use

3.2.1 Catia V5

Mostly of the design and all the process are done by this software. CATIA V5 are computer aided design tool. It's commonly used in engineering design and leading software in 3D CAD product. Besides designing, CATIA V5 also use to stimulate, analyze, and manufacture products in a diversity of industries including automotive, aerospace, consumer goods, and industrial machinery.

3.3 Preliminary Design and Mechanical Design

3.3.1 Part Design

The mechanical design are done in this software. The part design shown in Figure 3.2.

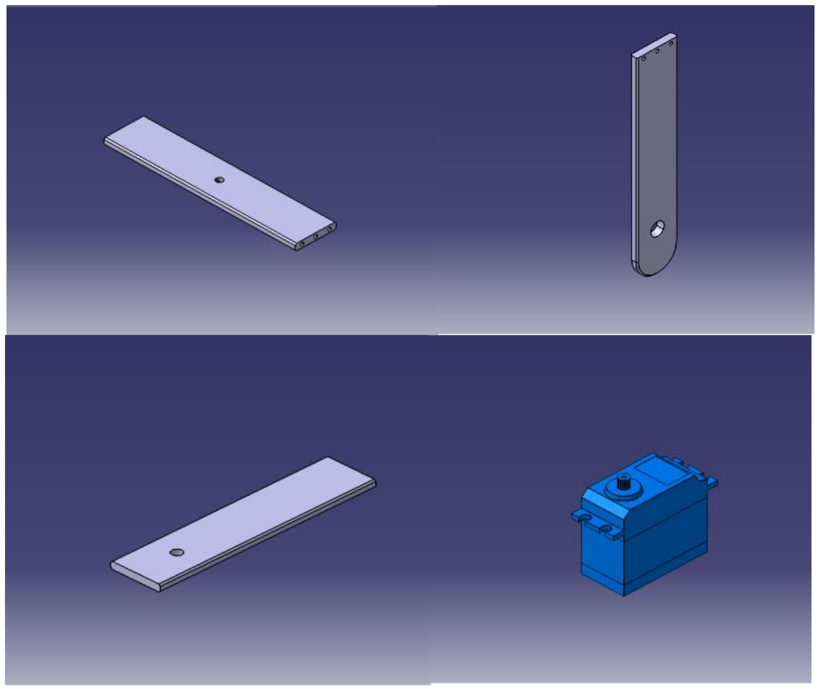

Figure 3-2: Part Design Before Assemble

3.3.2 Assembly Design

The part assembled in product design. In this product design, all part are being assembled together. It is crucial when designing the part to have the right dimension for each part to make it perfectly fit when assemble. The assembly design is shown in Figure 3.3.

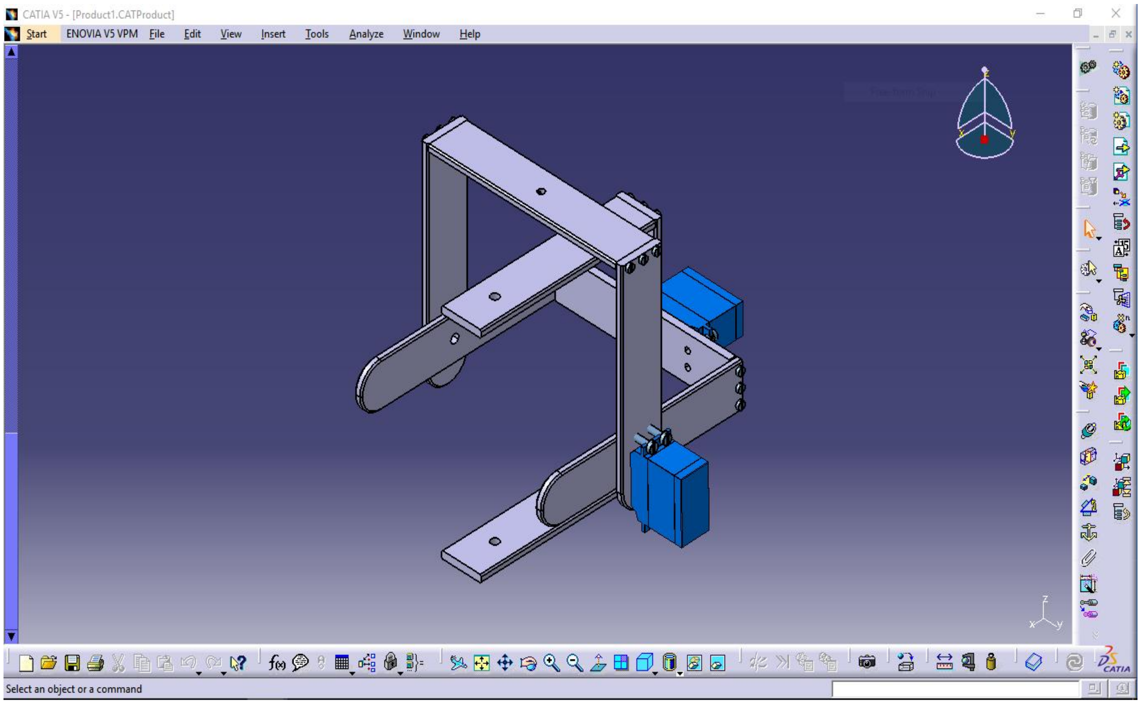

Figure 3-3: Assembled Design

3.3.3 Technical Drawing

Then the technical drawing are done in drafting based on industrial grade. First the part drawing is selected and drafting were produced. In the drafting, dimensioning is importance as it will make it easy to understand the drawing and part produce. When the drafting is done, template background is selected. The template consist of basic information for the part such as part name, design by who, and drawing scale. The example of technical drawing is shown at Figure 3.4.

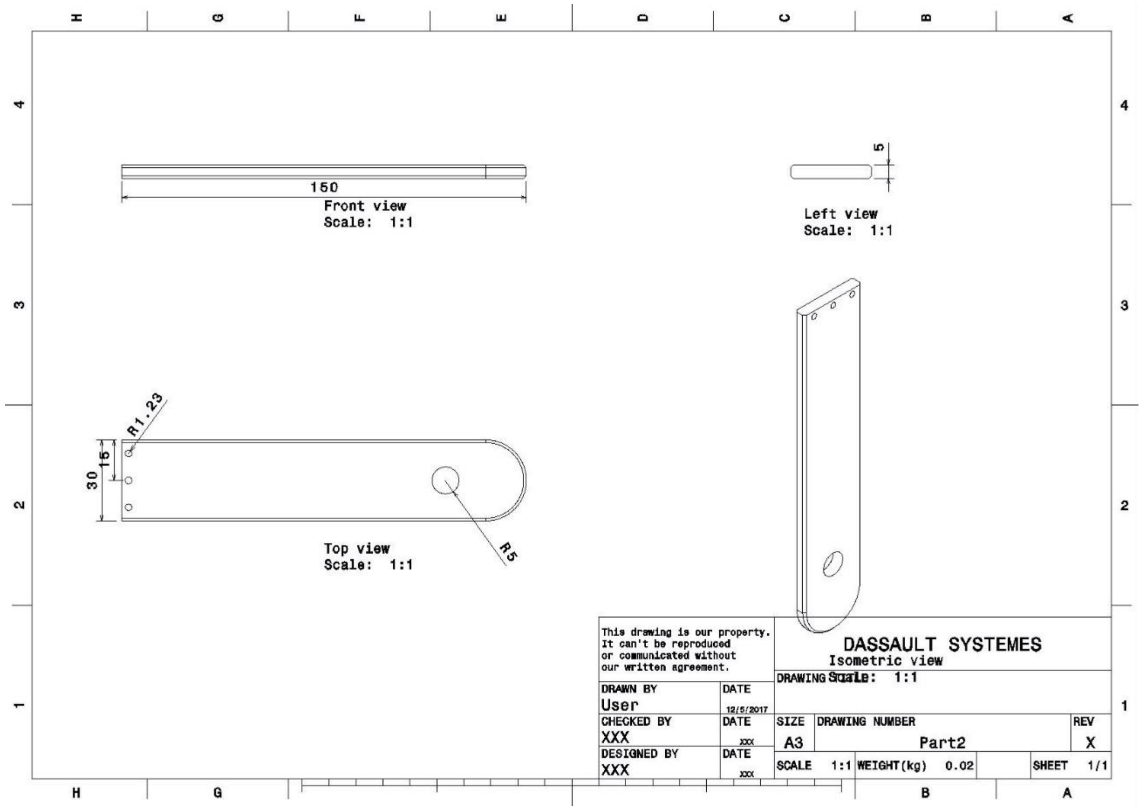

Figure 3-4: Technical Drawing

3.3.4 Exploded view of the product

Exploded view is to give a view how the part are being assemble. It's help other people to understand the idea of the product and how the parts are brings together. The explode view both produce on 3D drawing and Technical drawing. The exploded view is done by dissemble the product at x, y or z axis.

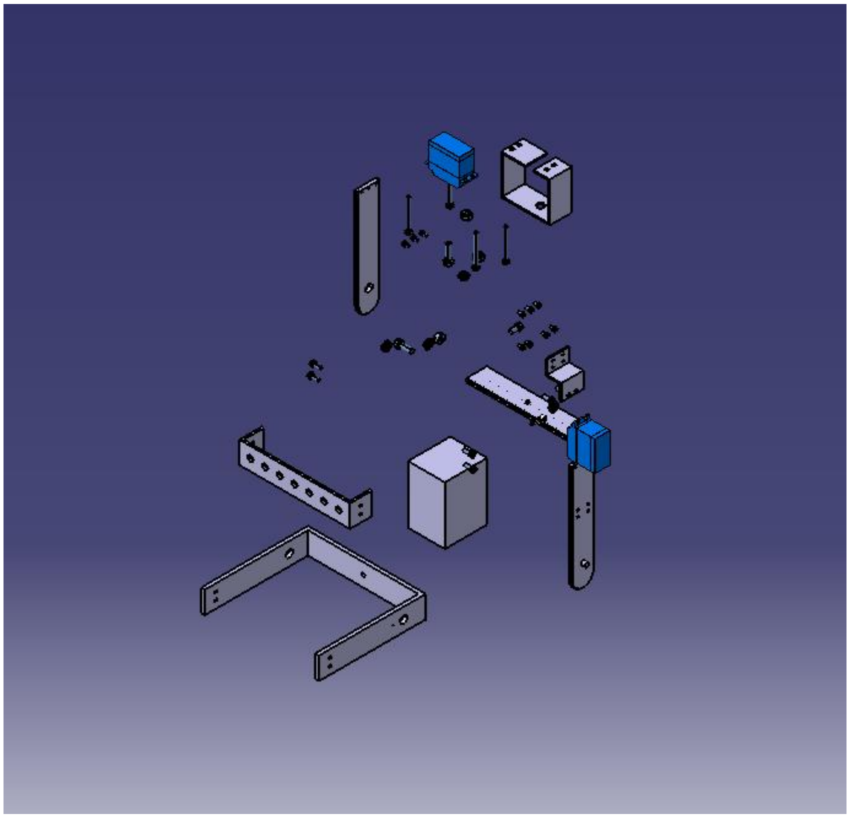

Figure 3-5: 3D exploded view

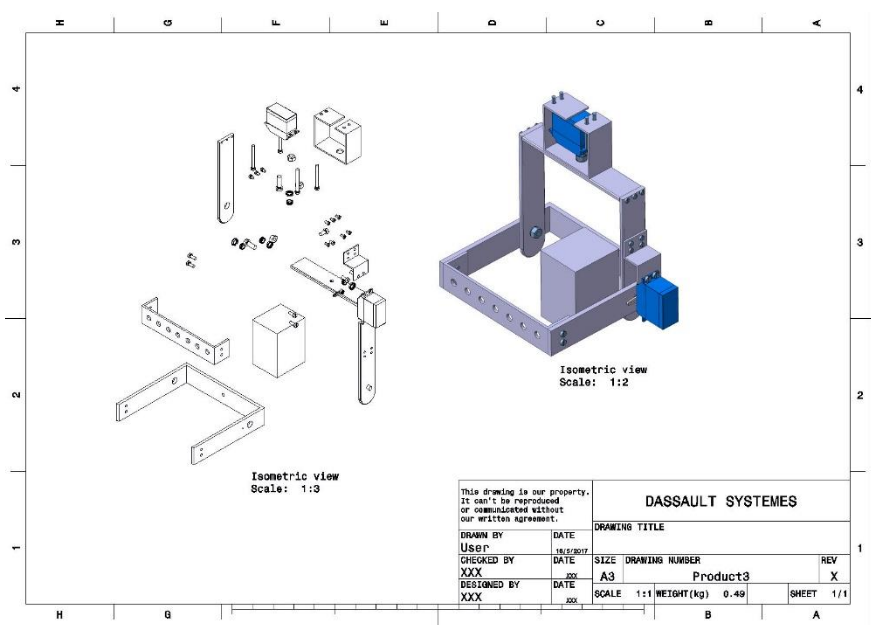

Figure 3-6: Exploded technical drawing