Design and Development of Interfacing Algorithm Controller for Telescope's Dome Rotary System

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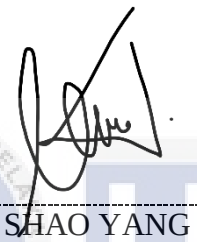
DECLARATION

I declare that this thesis entitled "Design and Development of Interfacing Algorithm Controller for Telescope's Dome Rotary System is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : 

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APPROVAL

I hereby declare that I have checked this report entitled “Design and Development of Interfacing Algorithm Controller for Telescope’s Dome Rotary System” and in my opinion, this thesis it complies the partial fulfillment for awarding the award of the degree of Bachelor of Mechatronics Engineering with Honours

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Date : 5 JULY 2021

DEDICATIONS

To my beloved mother and father.

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ABSTRACT

The robotic telescope in an observatory is a powerful instrument for observing celestrial activities such a Sun, Moon, Stars, pulsar and galaxies. It is used to carry out scientific research, as well as for cultural and religious purposes such as Astrology. The advancement in astronomy instrument technologies in past decades help us understand more about our final frontier. Modern telescopes are equiped with robotic control system to ensure a smooth and steady motion of the telescope when observing the sky through the night. Al-Khawarizmi Observatory has 2 motorised domes for rotation and shutter control, as well as a 2-axis robotic telescope. However, the motorised control of the dome is non-intuitive and out-dated. The astronomy observations are often done in night and human attention is needed throughout the process. To make the observation more convenient and to improve the observing efficiency, we sought to build a system with automation capability and while keeping a user-friendly interface. This project aims to construct an interfacing algorithm controller to control the rotation and shutter movements of observatory's dome. A controller software, Dome Controller written in Python is developed and its performance is analysed. Using a simplified small-scale observatory dome model, the accuracy and responce speed of the system is examined. At the end of the development, Dome Controller is able to perform generation of ephemeris data of the target astronimical object, control rotation and shutter motions of the dome and tracking of the target object, with sufficient speed and accuarcy.

ABSTRAK

Teleskop robotik dalam balai cerap merupakan sebuah alat instrumentatsi yang amat berguna untuk pemerhatian aktiviti angkasa seperi matahari, bulan, bintang, pulsar, dan galaksi. Teleskop robotik sering digunakan untuk tujuan saintifik, kebudayaan serta kaagamaan seperti astrologi. Kemajuan teknologi teleskop pada bererapa dekad yang lalu telah membantu manusia memahami tentang angkasa . Teleskop moden sering dilengkapi dengan sistem robotic untuk memastikan pergerakan yang lancar dan stabil semasa memerhati langit sepanjang waktu malam. Kubah teleskop di balai cerap Al-Khawarizmi mempunyai sistem kawalan bermotor untuk pusingan dan pengatup kubah, serta teleskop robotik 2 paksi. Walaubagaimanapun, pengawalan robotic untuk kubah ini adalah kurang intuisi dan ketinggalan zaman. Pemerhati haruslah sentiasa memerhati keadaan teleskop pada waktu malam sepanjang process pemerhatian. Kami ingin membuat sebuah sistem yang berkebolehan automasi dan masih senang diguna. Projek ini bertujuan membina sebuah alat kawalan algoritma untuk mengawal pergerakan pusingan dan pengatup kubah balai cerap. Sebuah perisisan pengawalan bernama Dome Controller yang berdasarkan bahasa pengaturcaraan Python telah direka dan diuji . Prestasi Dome Controller dianalisis dengan mengunakan sebuah model kubah balai cerap berskala kecil, untuk mengenalpasti ketepatan dan kepantasan tindak balas sistem tersebut. Pada akhirnya, Dome Controller berjaya menghasilkan efemeris objek astronomi yang diperlukan, mengawal pergerakan pusingan dan pengatup kubah serta operasi penjejakan objek astronomi tersebut dengan ketepatan dan kepantasan yang memuaskan.

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LIST OF SYMBOLS AND ABBREVIATIONS

AC	-	Alternating current
AI	-	Artificial Intelligence
ALT	-	Altitude
API	-	Application programming interface
AZ	-	Azimuth
CAD	-	Computer aided design
CCD	-	Charged coupled device
CPU	-	Central Processing Unit
DC	-	Dierct current
DEC	-	Declination
E	-	East
GRB	-	Gamma Ray Burst
GUI	-	Gamma Ray Burst
IDE	-	Integrated development environment
IP	-	Internet Protocol
IoT	-	Internet of Things
JPL	-	Jet Propulsion Laboratory
N	-	North
OS	-	Operating System
PID	-	Proportional, Integral and Derivative
RA	-	Right Ascension
RAM		Read only memory
USD		U.S. Dollar

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CHAPTER 1

INTRODUCTION

1.1 Background

The project idea of designing dan developing an interfacing algorithm controller came from an industry related problem. The Al-Khawarizmi astronomy complex, located in Kampung Balik Batu, Tanjung Bidara, Alor Gajah district, Melaka. It is about 50 minute by car from the Universiti Teknologi Malaysia Melaka. This observation site is owned by Malacca state government and operated by Malacca Mufti Department. The complex has 2 telescope domes, with robotic telescope mounts and they are calling for the hardware and software improvement for the dome after 13 years of its operation. This project is meant to be part of the development for the dome system in order to breeze a new life to it. Another related undergoing project is also being carried by Atiq Fajar bin Jamali with title "Embedded Controller-based Rotation Angle Control of Circular Rack and Pinion Telescope Dome at Al-Khwarizmi Observatory".

From the time when the al-Khwarizmi Observatoty was built to the point this project is carried out, several developments in enchancing the seeing capability and functionality of a telescope dome were made. For example, better control theories for radio telecope dome dan disc motion control [1], implementation of unattended observatory as well as smart observatory control using IoT.

The Al-Khawarizmi observatory is an official hilal for Astrofiqh observation. At the same time, it also serves the purpose of educating young scholars about astronomy. Therefore, it's desireable to reconstruct the existing system to help simplify the operation the observatory. In this project, the main interest is to create the interfacing algorithm controller wtih low cost instuments and provide an intuitive user interface for the system.

1.2 Motivation

My main motivation for this project is the need of providing a low-cost solution to help expanding the realm of astronomy to young children for educational purpose. The high tech equipments used in astronomy observation is very hard to find and expensive. I would like to create an afforable device which still packs essential functionalities to carry out the observation. A simple-to-use yet feature-packed control software would be an excellent stepping stone for the educational use.

While carrying out the development of the interfacing controller, the friendly community of astronomy gave me motivation and led me to develop interest in this subject. The open-source development in various type of hobby and professional observatories setup help me gain knowledge and confidence in making development of this subject.

Lastly, the growing market of in astronomy devices for amateur and hobby has strong trend in market size. An estimation of 345.1 million USD market size by 2026 is predicted by the reportsanddata.com [2]. This strengthen my confidence for carrying out this project.

1.3 Statement of Problem

The telescope is the doorway the astronomy research and investigation. Various kind of telescope was intoduce in the past from refractive telescope, reflective telescope, and radio telescope and now advance geosynchronous space telescopes. The fragile optical elements and electronic components are prone to damage in open space. Telescope dome is built to house the equipments for permanent installation and observation. The dome have a shutter which open up sideway or vertically to desired height if not fully, in order to expose the part of sky for observation. This prevent light pollution to spoil the images, besides stopping bird and nocturnal animal such as owl and bat from interferring the observation. In the operation which involves astronomy object tracking for extended period, the telescope would need to move along with the body in azmuith and alttude angle across the night sky, by the mean of robotic telescope mount. The obervatory dome will have to rotate and change the angle of

shutter opening periodically using motorised system. An interfacing system is needed here to control the motorised dome system automatically and communicate with the capture software as well as reacting to various climate condition such as rain, mist, etc.

1.4 Aim and Objectives

The aim of this project is to develop a low cost interfacing controller for rotary system of ground-based observatory dome. The following objectives are set in order to achieve the specificed aim:

i. To design the controller for dome rotation and shutter control.

ii. To develop the graphical user interface with the essential information of observer and tracked object.

iii. To analyse the accuracy of the developed system and its performance.

1.5 Thesis scope

The scope of this project will focus on the development of control algorithm and user interface for the dome motion control. The scope and limitations of the project includes:

- Dome motion calculation algorithm, for azimuth and altitude angle.

- Graphical interface of the system

- Communication protocol with peripheral

- Logging and debugging abilities

- Necessary hardware design

Motor drive controller and algorithm is out of scope for this project

1.6 Thesis organisation

The remaining parts of the thesis are organised as follow:

Chapter 2: The overview of the automated spectoscopy, from being proposed around 1986, until the recent development and interests.

Chapter 3: Describes the methodology of this research. The process of developing the interfacing controller and method of analysis for the system performance are presented in this chapter

Chapter 4: Discuss the result findings, analysis and discussion.

Chapter 5: Present the conclusion drawn form this project and the future direction.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter summaries the role of astronomy and observatories in Malaysia and Islamic culture, the type and functions of the official observatories are explained. After that, the development of automated system for use in observatories is discussed from the early day of automation to the recent developments in this field of research. Then, we look into the challenges faced by researchers and astronomers and how it's coped up with. Finally, the future and trends in the development of astronomy field is discussed.

2.2 Observatories in Malaysia

Malaysia is a country with rich Islamic culture infused into the lives of people. About 61.3% of population in Malaysia are muslim while the 19.8 are buddhishs, 9.2% Christians, 6.3% Hindus and 3.3% others. The rapid growth in the science of *falak* astronomy during the golden age of Islamic civilization created a stepstone for later astronomy research [3]. In the early 9th century during the rule of Caliph al-Ma'mun (813-833) of the Abbasid Caliphate, numerous reknown Muslim scientists from various fields of knowledge, in particualr astronomy were born. The Maragheh Obsevatory in the south of Tabriz and Ulugh Brgh Observatory in Samarkand are evidences of ancient astronomy effort and leave great impact and glory in the history of *falak* [3]. Therefore the Islamic culture and astrofiqh studies are tightly knitted for centuries.

In Malaysia, the official observatories are catogorized into 3 types which are federal observatory, astrofiqh observatory and high education obevatory [4]. The astrofiqh observaoties are operated by the State Mufti Department while the Federal Observatories are under the custody of National Space Agency or Agensi Angksa Nefara Malaysia (Angkasa) which was formerly known as Space Science Studies

Devision (BAKSA) [5]. It's a Malaysia government agency which was established to develop the education and research in space science. It also serve to help the government in implementing the National Space Policy or Dasar Angkasa Negara. Finally, the high education observatory is the observatory operated by Universiti Sultan Zainal Abidin (UniSZA), Terengganu. A study in developing countries by the Global Astronomy Survey (GAS) was conducted to identify the strengths and weakness of development in the field of astronomies in certain developed countries. Despite Malaysia was not involved in the survey, the analysis conducted by GAS revealed that Malaysia is still in the second stage in the survet, which comprises countries that have their own astronomical research and communities that understand astronomy [6], but still require support in various aspects, such as funds, education policies and more to help enrich the field of study.

The 8 official observatories in Malaysia are Sheikh Tahir Falak Centre, The national Planetarium Observatories, The KUSZA Observatory, Al-khwarizmi Falak Complex, The Al-Biruni Obervatory, Langkawi National Observatory, The Selangor Observatory and the Teluk Kemang Baitulhilal Complex. The Malaysia geological location is not ideal for astronomical observation due to the various weather condition such as thick cloud, high humidity, rainy seasons as well as light polution in urban area. [6] The Al-Khwarizmi Observatory in Malacca was built in 2002 and officially opened on 1st of December 2007. This seaside facility is 44m above sea level and prevent any obstruction of tall buildings and tree. In addition, it has a wide angle of west horizon view of 240° - 295° [7]. The observatories later became one of the official hilal observation sites for determining Ramadhan, Shahwal and Zuljijjah [8].

Despite the lack of supports for astronomy in Malaysian society, studies related to Islamic and Arabic studies sprout interest of local scholars, which covers a lot of issues such as discussion of the role of the al-Azhar University in dissemination of Islamic religious knowledge, the historical development in public instituition of Malaysian higher learning, the economic effect of the Julban riots during Mamluk period and many others [9].

2.3 Automated Spectroscopy

The technology development in electronics, computer and digital control during 1970s had changed the way engineers and researchers carry out their works. Automation in various industries is well received and resulted in high consistency with minimal human assistance [10]. As early as 1986, the astronmy community recognized that the possibilities of automating spectroscopic telescopes for better observation. Modern technologies, such as charged coupled device (CCD) sensors, robotic control and powerful computer processors, and digital storage are rare and expensive. However, [11] pointed out that the issue is the complications of implimenting the system at the time, not problems. Later in 2014, [12] share the thought about "the profit of automating the entire observe prosedure with a complex and expensive instument could be questionable…optimizing efficiency will bring much profit and scientific payback". The elephant in the room is that the value of the scientific instrument is only as much as the human insight. The cost for building and maintaining the instument can be extremely costly. In the other hand, low cost system will be much suitable and subtainable with less associated risk.

[13] addressed the need for a Robotic Telescpoe and the issues that must be considered in the design of the telescope. He proposed two requirements for automated spectroscopic observatories, based on robotic system to perform simple repetative tasks. Firstly, the system must be able to conduct observing procedure without frequent human input and attention. After that, the instruments and programs used must be well-defined and strictly constrained to precent any unwanted behaviours which are not design to handle by the automted system. These requirement for basic spectroscpoic automation become more important when more and more advanced robotic telescope emerged in recent years.

2.4 Challenges in Robotic Telescope

High power telescope such as radio telescope are use in deep space observation. These telescopes house high density imaging sensors and have the ability to resolve thousandths of an arcsecond (0.00028°) which make them useful for pulsar

and discovery of exoplanets. The use of robotic telescope provided a stable platform for celestial observation with improved accuaracy and reliability [14].

The upcoming challenge for bringing the better seeing capability to the telescope is the disturbance which can introduce noise to the images. The airflow into the the telescope dome through the window and shutter from a warm or cold environment will change the characteristics air, in particular refractive index of air. Nosov [15] studied this effect and found strong unstable stratification in front the entrance telescope mirror when dome opening is ascertained. Changings in temperature, humidity, and air pressure can all can produce this effect and degrade the seeing capability of the telescope. Another finding [16] shown that even a slight constant moving air across the surface of the mirror can have great effect in controlling the effect of temperature on mirror.

Research in smart control system and automation also poses a challenge for the researcher to improve the system for ease of use and better imaging qualities. Researcher opt for removing all unwanted influence of weather condition during the night sky observation. [17] tried to obtain theoritical results of air turbulance motion inside a closed dome room by numerical solving of boundary valve problem for Navier-Strokes equations, and successfully registered same result as the compact portable weather station. [1] proposed an optimal approach to control the radio telescope disc, while encountering the effect of winding blowing at the telescope.

Another challenge is to implement a manless system for remotely located observatories. The urban environment is not suitable for most astronomy observations due to air pollution and light pollution. For example, the Five-hundred-meter Aperture Spherical Telescope in GuiZhou, Southwest China is built in a large karst depression called Dawodang depression [18]. The location very far from the large city and only small villages in the area. The people living within 5 kilometers in the area are relocated to create a radio-quiet area. This make the researcher harder to access the facility and stay for long time. Some observatories are located in Antarctic and dessert, where the weather and sky condition are optimal for the astronomy observation, at the cost of uneasy access and maintenance. One notable example of remote control system for telecope is the ASTE (Atacama Submillimeter Telescope Experment) project. This