DRONE TRACKNG AND LOCALIZATION IN INDOOR 3D ENVIRONMENT

BY

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ABSTRACT

Radio Frequency Identification (RFID) is an information exchange technology based on RF communication. It is also provide solution to track and localize objects in the indoor environment. When RF transmitter is connected to the object, tracking and positioning can be performed using a wireless communication system. The technique that RF uses to locate objects is called RFID and labeled objects are called RFID tags.The technological progress has made the use of RFID tags without batteries and called passive tags, capable of recovering energy from the incoming RF signal. The reader can use the RF signal to transfer information from the reader to the tag. The tag antenna reflects a certain amount of energy that is being taken. By modulating this reflection, tags can send information. Tracking and localization of a mobile objects in an indoor environment have great significant attention due to the need of higher localization accuracy. RSS-based localization techniques are the major tools for tracking applications. This research work propose the method of localization that uses the RFID tagged drone combined with RSS value to improve the RFID based localization in indoor environment. This method provides solutions for the drone tracking problem. By measuring the RSS value between RFID tagged drone and reader, and calculate the distance between the tagged drone and atleast three readers using trilateration approach. Readers location are known and any error in measuring the distance influence drone location estimate. The localization method is implimented in MATLAB to simulate and evalute the performance of the proposed method. In this research work, localization method is implemeted to track the drone position with low localization error. The simulation environment is developed to evaluate the performance of the multiple RFID readers and the results have been compared. The localization error achieved with 4 multiple RFID readers and 8 multiple RFID readers were 0.81289 and 0.39793 meter respectively. The performance of the localization method is also compared with other RFID localization previous related works. The results have shown that the performance in localization and tracking of tagged drone in indoor environment has been improved by 42.9% when 8 multile RFID readers are applied in the localization area.

خلاصة البحث

تحديد الترددات الراديوية (RFID)عبارة عن تقنية لتبادل المعلومات تعتمد على الاتصالات اللاسلكية. كما أنه يوفر حلاً لتتبع الكائنات وتوطينها في البيئة الداخلية. عند توصيل مرسل RF بالكائن ، يمكن إجراء التتبع وتحديد المواقع باستخدام نظام اتصال لاسلكي. يطلق على تقنية RF لتحديد موقع الأشياء اسم RFID وتسمى الكائنات ذات العلامات .RFID وقد جعل التقدم التكنولوجي استخدام علامات RFID بدون بطاريات ودعا العلامات السلبية ، وقادرة على استعادة الطاقة من إشارة RF الواردة. يمكن للقارئ استخدام إشارة التردد اللاسلكي لنقل المعلومات من القارئ إلى العلامة. يعكس هوائي الوسم كمية معينة من الطاقة التي يتم أخذها. عن طريق تعديل هذا الانعكاس ، يمكن للعلامات إرسال المعلومات. تتبع وتعريب الأجسام المتحركة في بيئة داخلية تحظى باهتمام كبير بسبب الحاجة إلى دقة تعريب أعلى. تقنيات التعريب المستندة إلى RSS هي الأدوات الرئيسية لتتبع التطبيقات. يقترح هذا العمل البحثي طريقة التعريب التي تستخدم الطائرة بدون طيار التي تحمل علامات RFID مع قيمة RSS لتحسين التوطين المستند إلى RFID في البيئة الداخلية. توفر هذه الطريقة حلولاً لمشكلة تتبع الطائرات بدون طيار. عن طريق قياس قيمة RSS بين الطائرة بدون طيار والقارئ RFID ، وحساب المسافة بين الطائرة بدون طيار الموسومة وثلاثة القراء على الأقل باستخدام نهج ثلاثية. موقع القراء معروف وأي خطأ في قياس تأثير مسافة تقدير موقع الطائرة بدون طيار. يتم وضع طريقة التعريب في MATLAB لمحاكاة وتقييم أداء الطريقة المقترحة. في هذا العمل البحثي ، يتم تنفيذ طريقة التعريب لتتبع موقف الطائرة بدون خطأ تعريب منخفض. تم تطوير بيئة المحاكاة لتقييم أداء أجهزة قراءة RFID المتعددة وتمت مقارنة النتائج. كان خطأ التوطين الذي تحقق مع 4 أجهزة قراءة RFID متعددة و 8 أجهزة قراءة RFID متعددة 0.81289 و 0.39793 متر على التوالي. تتم مقارنة أداء طريقة التعريب أيضًا مع الأعمال السابقة ذات الصلة بترجمة .RFID أظهرت النتائج أن الأداء في توطين وتتبع الطائرات بدون طيار الموسومة في البيئة الداخلية قد تحسن بنسبة 42.9 ٪ عندما يتم تطبيق 8 أجهزة قراءة RFID متعددة في منطقة الترجمة.

APPROVAL PAGE

I certify that I have supervised and read this study and that in my opinion, it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Master of Science (Communication Engineering)

Mohamed Hadi Habaebi
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Ahmad Faris Ismail
Dean, Kulliyyah of Engineering

DECLARATION

I hereby declare that this dissertation is the result of my own investigations, except where otherwise stated. I also declare that it has not been previously or concurrently submitted as a whole for any other degrees at IIUM or other institutions.

Rashid Omar Khamis

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LIST OF ABBREVIATIONS

2D	2-Dimension
3D	3-Dimension
EM	Electromagnetic Wave
AOA	Angle of Arrival
GPS	Global Positioning System
HF	High Frequency
IR	Infrared
ISO	International Standard Organization
kNN	k Nearest Neighbor
LAN	Local Area Network
LF	Low Frequency
LOS	Line of Sight
MSE	Mean Square Error
MW	Microwave
PASS	Proximity-detection-based Augmented System Simulator
PF	Particle Filter
QoS	Quality of Service
RF	Radio Frequency
RFID	Radio Frequency Identification
RMSE	Root Mean Square Error
RSS	Received Signal Strength
RTLS	Real Time Localization System

SUZA	State University of Zanzibar
TDOA	Time Difference of Arrival
TOA	Time of Arrival
UHF	Ultra High Frequency
USDOD	United State Department of Defence
UWB	Ultra Wide Band
WCL	Weighted Centroid Localization
WiFi	Wireless Fidelity
WLAN	Wireless Local Area Network
WSN	Wireless Sensor Network

LIST OF SYMBOLS

A	received signal strength at one meter distance
c	scaling constant based on the tag density
D	distance between reader and tag
d_i	time duration in which i tag remains in the reading area of the reader
D_i	predicted distance from tagged drone to the i readers
G_r	receiver gain antenna
G_t	transmitter gain antenna
M_{AN}	number of readers
N	number of intervals
N_{AN}	number of reference tags
P_r	received power
P_t	transmitted power
S_{ij}	received signal strength between i reader and j tag
t	time duration
v	estimated target spped
x	estimated value of the drone in the x-axis
x^	actual value of the drone in the x-axis
x_i	fixed value of i reader in the x-axis
y	estimated value of the drone in the y-axis
y^	actual value of the drone in the y-axis
y_i	fixed value of i reader in the y-axis
z	estimated value of the drone in the z-axis

z^	actual value of the drone in the z-axis
z_i	fixed value of i reader in the z-axis
β	pathloss exponent
λ	wavelength

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND OF THE STUDY

Radio frequency identification (RFID) is a technology that uses electromagenetic signals to exchange information between RFID reader and RFID tag to localize and track the attached tag (Alsalih, et al., 2014). Different from conventional bar code labeling, RFID allows localization from a distance with non line of sight (Xie, et al., 2017). Figure 1.1 shows the RFID system which consitsts of three parts; a reader, a tag and antenna which are used to transmit and receive radio waves in the air. With the unrivalled increase in capacity and low cost of electronics, the RFID feature has become increasingly important for object tracking and inventory management. As a result, RFID is increasingly being used in many fields including; supply chain management (Alsalih, et al., 2014), health care (Ruan, et al., 2016), retail (Nayak, et al., 2015), hospitality (Kulshrestha, et al., 2018), food industry and airline industry (Yang, 2014). A number of standards have been developed for regulating RFID industry such as International Organization for Standardization (ISO), International Electrotechnical Commission (IEC), ASTM International (Nayak, et al., 2015), DASH7 Alliance and EPCgbobal (Xie, et al., 2018). Based on RFID technology and other technologies such as bar codes and 2D codes, Internet of Things have grown at an unprecedented rate in identifying objects which are being used in a daily life. (Ruan, et al., 2016).

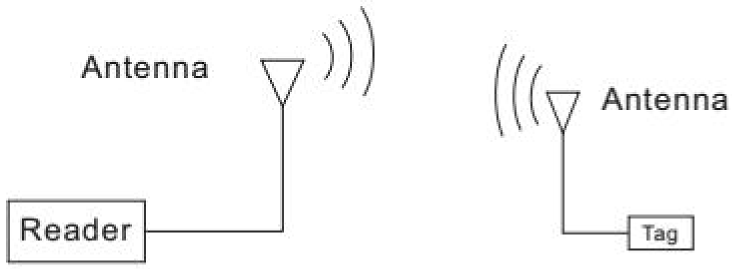

Figure 1. 1: Basic Structure of RFID System (Li, Y. 2013).

Many wireless localization technologies have been used to track or localize an object. The first technology in application in that aspect was the use of acoustic waves to localize submarines for military use (Nayak, et al., 2015). Then came the use of radar for the deployment of aircraft which played a significant role in World War II (Tahat, et al., 2016). After World War II, the most common wireless tracking application has been the Global Positioning System (GPS) which was developed by the US Department of Defense (USDOD). The GPS receiver uses arrival time of signals from satellites to estimate the position. The use of wireless local area network (WLAN) device has also been developed to localize objects according to the newly acquired Received Signal Strenth (RSS) (Trogh, 2019). Infrared waves also has been used to estimate the location of certain objects such as mobile robots (Savachkin & Gimpilevich, 2018), while ultrasonic is used in human interface applications (Berz, et al., 2017).

Various techniques have been approved to localize an object in indoor environment. Some of these techniques are LAN, ultrasonic and infrared. In comparison with these localization techniques, RFID has some essential advantages. The characteristics of non-line of sight readability, high data rate communications, security, compactness and low cost have made RFID a good technique for tracking objects in an indoor environment (Alsalih, et al., 2014). Different parameters such as

Time of Arrival (TOA), Time Difference of Arrival (TDOA) and Received Signal Strength (RSS) can be used to estimate the location in RFID systems (Huang, et al., 2014). Due to the limited reading range of RFID systems, TOA and TDOA will be very small (less than 1 nano seconds) in different receiving antennas that will be measured by simple readers. This is why RSS based method is the most suitable way in determing the location in indoor environment under the RFID systems.

1.2 PROBLEM STATEMENT AND ITS SIGNIFICANCE

In the last decade, the issue of drone localization system that uses passive RFID tags in indoor environment has been one among the interesting topics for research. Significantly, this system should work in all circumstances and should contain only a minor error in localization. However, the environment in which the RFID tags work is not friendly. Reflections on floors, walls and furniture tend to make localization process more challenging. Another problem is that in the UHF band, only a very small range is used for unauthorized use. RFID UHF tags can contain low cost, battery less and relatively long read distance. In (Wen, et., 2018) the issue of localization systems based on RFID tags have been widely studied. However, still there is a need for improvement of the results to be found. Thus, because UHF RFID tags are widely spread, the localization system based on these tags is still more attractive.

1.3 RESEARCH OBJECTIVES

The major aim of this research is to improve the tracking accuracy and estimate the location of the RFID tagged drone using sensory data in an indoor environment without the benefit of the GPS positioning. Specifically, this research is conducted to achieve the following purposes:

1. To propose a localization method for passive UHF RFID tags which is able to track and estimate the location of RFID tagged drone in an indoor environment, and
2. To evaluate and benchmark the proposed method, under multiple RFID readers design to improve the localization accuracy in indoor environment against other methods.

1.4 RESEARCH METHODOLOGY

The methodology which was used in this research consisted of three aspects; the RFID reader, a number of passive RFID tags and the environment infrastructure. First of all, the RFID tag was attached to the drone which was to be tracked. Then the infrastructures was made to includes the servers which were deployed in the localization area where the drone was moving. The RFID reader could communicate with the server using wireless networks such as WLAN. Considered that the RFID reader was integrated with the circularly polarized antenna. The RFID tag with the drone had a height above the ground, and circular reading range. The number of multiple RFID readers were deployed in the localization area. Each reader location was stored in advance at the server in association with the tag's ID. Whenever the readers detect a tag, it could calculate its distance with the help of trilateration approach using RSS based technique to estimate the drone location. For each aspect, Figure 1.2 shows summary of the flow chart of the research methodologies.

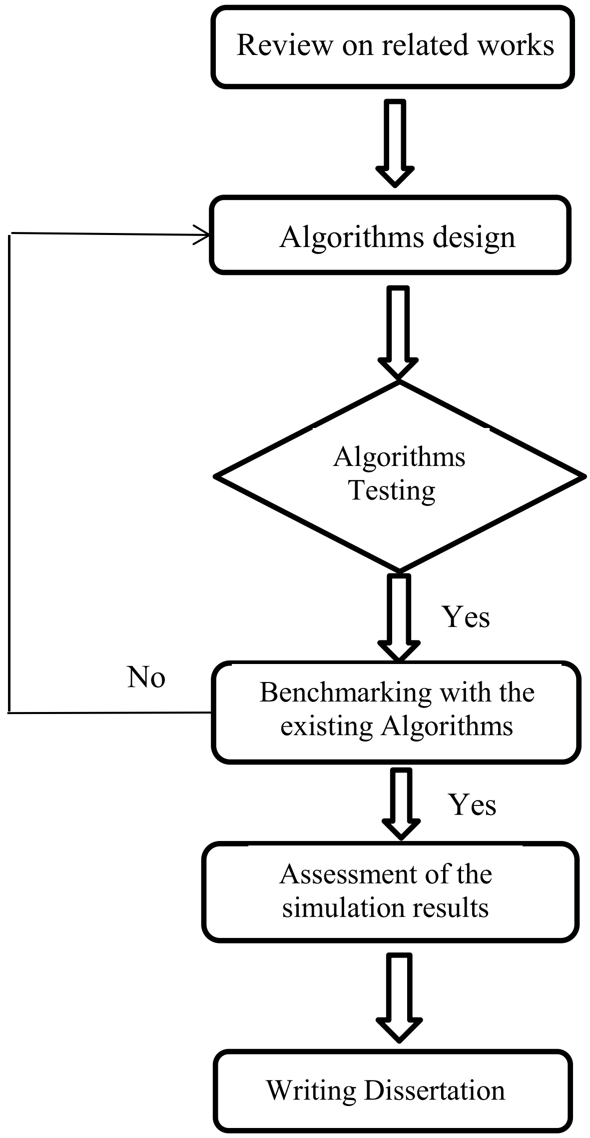

Figure 1. 2: Flow Chart of the research methodology

1.5 RESEARCH SCOPE

This research has mainly focused on the use of the RSS technique under RFID based localization system. This system is considered to be simple, cost effective and precise for drone tracking in an indoor environment. For the purpose of significantly minimizing the localization error and maintain the position of the drone in a real time using translational directions of the drone.

1.6 OGRANIZATION OF THE DISSERTATION

The main focus of this research is the studying of the drone tracking and localization in indoor environment. It has been made and developed into five chapters which are as follows.

Firstly is chapter one which provides the general introduction of the research. It consists of the background of the research, problem statement and its significance, objectives of the research, research scope and research methodology. Next is chapter two which is covered by the review of different literatures which are relevant to this research. This chapter focuses on the previous researches. It points out the researches which have been done at different stages, whereby attention is given to the great achievements done in the area. It summarises the related works by providing the strengths and the gaps evidencing the relevancy of this research. Moreover chapter three describes methodology used in doing this research in particular, the designing of the system model as well as the employed algorithms that were used in a drone tracking to localize its potision and velocity in indoor environment. The fouth chapter gives the analysis and evaluation of the simulated results which were obtained as performed between the proposed method and the previous works. Chapter five summarizes the whole research work and provides recommendations and insight for further studies in this area.

CHAPTER TWO

LITERATURE REVIEW

2.1 INTRODUCTION

The aims of this chapter is to review other works which are closely related to the study and the basic concept of research. Since the study is based on tracking and localization of the drone in indoor environment, in this chapter, the background and an overview of RFID system which describe the basic concepts of tracking and localization have been discussed. Generally an overview of localization is also presented together with a summary of related works, characteristics and applications.

2.2 RFID OVERVIEW

RFID is a popular data exchange technique which is widely applied for electronic passport, tracking, supply chains, industrial automation, mining securities, hospital, asset management and pharmaceuticals. There are many RFID applications, the list cannot be fully exhausted here. Further examples of RFID applications can be found in the RFID Journals and RFID handbooks (Finkenzeller, K. 2010).

The simplest RFID system contains of two main elements; a tag (transponder) and a reader (interrogator). The tag and the reader normally communicate with the radio waves. The radio frequency (RF) bands which are commonly used in RFID system are; 120-150 kHz Low Frequency (LF), 13.56 MHz High Frequency (HF), 433MHz, 868-870 MHz and 902-928 MHz Ultra High Frequency (UHF) and 2.4-5.8 GHz Microwave Frequency (MW) (Nayak, et al., 2015). RFID systems in LF and HF operate by inductive coupling. On the contrary, the UHF and MW systems are