



Anand Nagar, Krishnankoil - 626126, Srivilliputtur (via), Virudhunagar District, Tamilnadu.

APPLICATION FOR ADMISSION TO Ph.D. PROGRAMMES

Date of Application:26-11-2020

Department	COMPUTER SCIENCE AND ENGINEERING	Application No.	202020030
Area of Research	ARTIFICIAL INTELLIGENCE / MACHINE LEARNING, DISTRIBUTED CLOUD COMPUTING	Research Mode	PART TIME

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Religion	HINDU	Martial Status	MARRIED
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Physically Challenged	NO	Type of Disability	-
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Qualification						
Degree	Discipline	College/university	Year Passed	AVG/CGPA	Class	Mode
MTECH	DISTRIBUTED COMPUTING SYSTEMS	PONDICHERRY UNIVERSITY	2007	6.7	FIRST	REGULAR
BTECH	COMPUTER SCIENCE ENGINEERING	PONDICHERRY UNIVERSITY	2004	6.8	FIRST	REGULAR

Experience					
Organization	Designation	Experience From	Experience TO	Work Nature	
HONEYWELL TECHNOLOGY SOLN PVT LTD	SR. ADVANCED SOFTWARE ENGINEER	2019-10-29	2020-11-26	ENGINEERING R&D	
RESIDEO(ORIG HONEYWELL)	TECHNOLOGY SPECIALIST	2014-07-28	2019-06-28	ENGINEERING R&D	
INFOSYS LTD	TECHNOLOGY LEAD	2010-01-03	2014-07-18	ENGINEERING R&D	
HCL LTD	MEMBER TECHNICAL STAFF	2007-07-11	2010-02-23	ENGINEERING R&D	

Payment Details				
Transaction ID	Reference	Date of transaction	Amount	Status
202020030_201126181749	VHD49497533689	26-11-2020	600	SUCCESS

REAL-TIME ANOMOLY DETECTION IN PHYSICAL ACCESS CONTROL SYSTEM(PACS) USING PREDICTIVE MODELING

STUDENT NAME: Vijayaram Boopalan
COURSE NAME: Doctor of Philosophy (Computer Science Engineering)
DEPARTMENT: Department of Computer Science and Engineering
SUPERVISOR: YTD
DATE OF SUBMISSION: 15 Nov 2020

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ABSTRACT

In recent years machine learning based anomaly detection is gaining popularity in Intrusion detection system. Once upon a time physical security is of utmost importance as 1st line (SL-1) of defence to protect the assets like Buildings, Industries, even in providing National Security protecting the people. As the Internet era started security solutions based on hardware and software had become the ubiquitous 2nd line (SL-2) of defence using Physical Access Control Systems (PACS) consisting of components like Access point, Personal Identity Verification (PIV) credentials, credential reader and keypad, biometric reader, control panel, access control server, credential holder data repository, auxiliary systems (fire alarm systems, surveillance systems, smoke detectors, evacuation systems). With the advancements of Artificial Intelligence and Machine Learning, Systems are developed to be more intelligent to detect anomalies based on the historical data. In the paper we will analyse different anomaly prediction algorithms and propose a predictive modelling solution using Clustering Based Local Outlier Factor (CBLOF) and Histogram Based Outlier Score (HBOS) with the help of Python library (PyOD-Python Outlier Detection) to detect real time anomaly based on the PACS access events and audit logs.

INTRODUCTION

PACS

Physical Access Control Systems (PACS) is a system provided as a solution in combination with hardware products like access controller panels, card readers, biometric readers, siren alarms, cameras, smoke detectors, etc., and software which controls the management of credentials, rules, access control servers, etc., Some of the common components in every PACS are

Access Point

Access point is the first interaction point of the PACS system where end-user interacts. Some of the examples of access point are gates with access card reader / biometric reader mounted, turnstiles with access card reader / biometric reader mounted, doors with access card reader / biometric reader mounted.

PIV Credential

Personal Identity Verification (PIV) Credential to either physically or logically access the PACS. These credentials are used to validate the person and act (allow / deny) access to the physical location based on the rules set in the PACS.

Card Reader / Bio Metric Reader

Card Reader / Bio Metric Reader are physical devices used to read data from PIV credential and sends the data to access controller panel to authenticate the PIV credential and take decision to allow/deny based on the rules set in the PACS. Access Card / Badge Number, Biometric Fingerprint, Facial Image and IRIS scan are some of the PIV credentials used.

Control Panel

It's the heart of the Access control system to receive the reader data and verifies its authenticity against the PIV credential repository or rules set to allow/deny access to the location. This decision signals the reader, door / gates to open door / remain closed with green/red LED indicators in the reader.

Access control server

Access control server is a set of software for managing PIV credentials and configuring access and privileges for the end-users (Card / badge Holders).

Credential Holder Repository

It's the repository used by PACS software to store the PIV credentials and access privileges. Control Panel uses this data to grant/deny the access to the end-users.

Auxiliary Systems

Auxiliary systems are those systems which integrates with PACS to provide additional level of security features like Fire Alarm System, Elevator System, Evacuation System, Surveillance system, etc, These systems / products when combined with PACS will provide robust security for the building/premises providing utmost safety and comfort for the people.

PROBLEM STATEMENT

Overview

Most of the PACS behaves based on the predefined set of the rules and access privileges configured. There are times threats arise out of insider authorized persons and it becomes difficult to identify those insider threat as they hold valid PIV credentials and are authorised to enter or access those restricted locations. So manual processing or investigating any insider threat security

incident becomes tedious, time consuming and more over breaks the dignity of the officials by putting dignified employees under the investigation umbrella. So, the need to intelligently identify the insider treat has become inevitable now-a-days as part of every PACS security solutions. Most of the security solutions providers lacks on this feature due to the unavailability of the direct solution to detect those incidents.

Research Question/Hypothesis

Many Anomaly detection algorithms are available and used for various other purposes, but to predict or identify the insider intrusion based on PACS events data in real-time is of less use due to its drawback of high false-positive detection result. So a detailed analysis of the PACS system data analysis and transformation is required, along with combined anomaly detection algorithms with relevant hyper-parameters are of utmost import to get real-time detection/prediction solution with less false-positive detection rate.

OBJECTIVES AND AIMS

Overall Objective

A Predictive analytics model / system should be designed and put in place to automatically detect those insider threats or anomaly based on the access control event data and audit log pattern using machine learning training and prediction data model.

Specific Aims

Through this research a more robust real-time prediction model is proposed based on Clustering Based Local Outlier Factor (CBLOF) and Histogram Based Outlier Score (HBOS) with the help of Python library (PyOD-Python Outlier Detection) for anomaly detection based on the historical and live access control event and audit data.

RESEARCH DESIGN AND METHODS

Overview

This research is to propose a robust real-time prediction model based on Clustering Based Local Outlier Factor (CBLOF) and Histogram Based Outlier Score (HBOS) with the help of Python library (PyOD-Python Outlier Detection) for anomaly detection based on the historical and live access control event and audit data.

Please find below the code snippet for real-time prediction model. Prediction model design and method evaluation is in progress...

```
import pandas as pd
import numpy as np
import matplotlib.pyplot as plt
from pyod.models.lof import LOF
from pyod.models.mcd import MCD
from pyod.models.auto_encoder import AutoEncoder
from pyod.models.lscf import LSCF
from pyod.models.cblof import CBLOF
from pyod.models.hbos import HBOS
import timeit
import swifter
import pickle

data = pd.read_csv('evlog2.csv', header = 0, names = ['BADGENO', 'LOGDEVID', 'REC_DAT'])
data = data[15000000-3000000:]
starttime = timeit.default_timer()
class rtad():
    def __init__(self):
        i = 1
    def trigtrain(self, data):
        def dateformat(df):
            df['date'] = 0
            df['hour'] = 0
            df['date'] = df.swifter.apply(lambda row : row['REC_DAT'].split()[0], axis = 1)
            df['hour'] = df.swifter.apply(lambda row : float(row['REC_DAT'].split()[1].split(':')[0]) + float(row['REC_DAT'].split()[1].split(':')[1]) / 60, axis = 1)
        dateformat(data)
        starttime = timeit.default_timer()
        data['mean'] = 0
        data['std'] = 0
        data['acc_mean'] = 0
        data['acc_std'] = 0
```

REFERENCES

ADAPTIVE LOAD BALANCING BASED ON CONTEXT AND SITUATIONAL AWARENESS OF TARGET

STUDENT NAME: Vijayaram Boopalan
COURSE NAME: Doctor of Philosophy (Computer Science Engineering)
DEPARTMENT: Department of Computer Science and Engineering
SUPERVISOR: YTD
DATE OF SUBMISSION: 11 Nov 2020

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ABSTRACT

Load Balancing application or services in a high scale cloud or an enterprise infrastructure is inevitable to achieve reliability and scalability of the system. Be it a physical load balancer or virtual load balancer or a cloud load balancer, its primary job is to route client traffic to all servers configured. There are more complex algorithms involved in different types of load balancers to decide on routing traffic to the server for processing the client requests. Most of the algorithms do not consider the characteristic and context of the different services running in the participating servers. So, it is extremely important to know the current situation context and characteristic of different services before the traffic is routed simply based on the predefined set of algorithms or rules. In this paper we will provide the system and methods to consider the current situation context and characteristic of the different services as part of the application level load balancing to provide optimal performance and efficient dynamic load balancing.

INTRODUCTION

L7 Load Balancer

In the OSI reference model, layer 7 is called Application Layer (Http/Https). Application Layer or Layer7(L7) Load Balancer is used for routing client traffic to all the participating server based on context switching, it uses the request HTTP header, Session ID, URI, Cookies and sometime HTML form data to route the request to different servers.

Load Balancer Algorithms

Load balancer algorithms are used for deciding which request has to be routed to which server for processing based on various parameters defined in the algorithm. Some of the commonly used algorithms are Round Robin, Weighted Round Robin, Least Connection, Weighted Least Connection, Resource based (Adaptive), Resource based (SDN Adaptive), Fixed Weighting, Weighted Response Time, Source IP Hash, URL Hash, etc. These servers which in turn host services to process those requests and respond back. Most of the real time systems involving highly intensive traffic fails to do effective load balancing due to lack of situational context and dynamic characteristic of the server, as L7 load balancers are preloaded with standard algorithms mentioned above without any contextual knowledge of the system.

Round Robin

Round-robin load balancing is one of the simplest and most used load balancing algorithms. Client requests are distributed to application servers in rotation. For example, if you have three application servers: the first client request to the first application server in the list, the second client request to the second application server, the third client request to the third application server, the fourth to the first application server and so on.

This load balancing algorithm does not take into consideration the characteristics of the application servers i.e. it assumes that all application servers are the same with the same availability, computing and load handling characteristics.

Weighted Round Robin

Weighted Round Robin builds on the simple Round-robin load balancing algorithm to account for differing application server characteristics. The administrator assigns a weight to each application server based on criteria of their choosing to demonstrate the application servers' traffic-handling capability. If application server #1 is twice as powerful as application server #2 (and application server #3), application server #1 is provisioned with a higher weight and application server #2 and #3 get the same weight. If there five (5) sequential client requests, the first two (2) go to application server #1, the third (3) goes to application server #2, the fourth (4) to application server #3 and the fifth (5) to application server #1

Least Connection

Least Connection load balancing is a dynamic load balancing algorithm where client requests are distributed to the application server with the least number of active connections at the time the client request is received. In cases where application servers have similar specifications, an application server may be overloaded due to longer lived connections; this algorithm takes the active connection load into consideration.

Weighted Least Connection

Weighted Least Connection builds on the Least Connection load balancing algorithm to account for differing application server characteristics. The administrator assigns a weight to each application server based on criteria of their choosing to demonstrate the application servers' traffic-handling capability. The Loadmaster is making the load balancing criteria based on active connections and application server weighting.

Resource Based (Adaptive)

Resource Based (Adaptive) is a load balancing algorithm that requires an agent to be installed on the application server that reports on its current load to the load balancer. The installed agent monitors the application server's availability status and resources. The load balancer queries the output from the agent to aid in load balancing decisions.

Resource Based (SDN Adaptive)

SDN Adaptive is a load balancing algorithm that combines knowledge from Layers 2, 3, 4 and 7 and input from an SDN Controller to make more optimized traffic distribution decisions. This allows information about the status of the servers, the status of the applications running on them, the health of the network infrastructure, and the level of congestion on the network to all play a part in the load balancing decision making.

Fixed Weighting

Fixed Weighting is a load balancing algorithm where the administrator assigns a weight to each application server based on criteria of their choosing to demonstrate the application servers' traffic-handling capability. The application server with the highest weight will receive all the traffic. If the application server with the highest weight fails, all traffic will be directed to the next highest weight application server.

Weighted Response Time

Weighted Response Time is a load balancing algorithm where the response times of the application servers determine which application server receives the next request. The application server response time to a health check is used to calculate the application server weights. The application server that is responding the fastest receives the next request.

Source IP Hash

Source IP hash load balancing algorithm that combines source and destination IP addresses of the client and server to generate a unique hash key. The key is used to allocate the client to a particular server. As the key can be regenerated if the session is broken, the client request is directed to the same server it was using previously. This is useful if it's important that a client should connect to a session that is still active after a disconnection.

URL Hash

URL Hash is a load balancing algorithm to distribute writes evenly across multiple sites and sends all reads to the site owning the object.

PROBLEM STATEMENT

Overview

While most of the load balancing algorithms focus on the decisions based on the predefined logic or the current state data of the servers, it lacks in proper decision making due to the unavailability of the situational context and importance of the difference services running in the different servers. Though weighted round robin algorithms take the weight value of the server for decision making, it lacks in situational context of the server and the current service state. Let's say a server is running few services like provisional device service, registration device service, device api service, device telemetry processing service, etc. Out of the above services, registration and provisional device service are more important at any point in time for the end-users to get their first unbox experience of their consumer IOT device. So, in addition to providing weightage to server, its also important to provide dynamic weightage for those critical services based on its current context and situational state for making load balancing decision making, in order to effectively use the system resource without being compromising the customer user experience and trust.

Research Question/Hypothesis

Researches on Adaptive Software Defined Network(SDN) based SDN architecture that decouples the data and control planes, seems to be promising, but the algorithm used are of common ones which does not considers the situational metrics of those critical services running the server.

In the Research Paper "Adaptive Consistency for Distributed SDN Controllers", Mohamed Aslan etal.¹, use of adaptive controllers into software-defined networking (SDN) and propose the use of adaptive consistency models in the context of distributed SDN controllers. The comparison of their research showed Adaptive controller are more resilient and effective in load balancing even during sudden burst in network conditions.

OBJECTIVES AND AIMS

Overall Objective

With the advancement of technology and Internet Of Things (IoT) making its place everywhere, the importance of the IoT device software providers QoS and QoE becomes very important and challenging to achieve. Though make larger cloud providers are bringing in effective cloud solutions through their PaaS and IaaS offerings, the need for tailored load balancing algorithm in combination of their IaaS offering is inevitable for bringing the better customer QoE.

Specific Aims

Though hardware level and network level improvements can be brought in for effective load balancing, the need for the more granular level decision making based on the situational context of the service running in different participating server is much required, and this need a shift in load balancing algorithm design from a traditional standard algorithms which just focus on distributing the load to different server either randomly or using the predefined weightage setting and static resource state rules like number of request the server is servicing, number of system cores unutilized, etc.

Through this research a more systematic and dynamic decision making algorithm is proposed considering the current situational context of the services the server is currently running.

RESEARCH DESIGN AND METHODS

Overview

This research is to propose a novel enhanced adaptive target context and situation aware SDN based load balancing algorithm, where granular level weightage is also given to the services running based on their importance in the solution and also its situational behaviour is considered for load balancer decision making of routing traffic to the server which host/runs those services.

Algorithm design and method evaluation is in progress...

REFERENCES

¹ M. Aslan and A. Matrawy, "Adaptive consistency for distributed SDN controllers," *2016 17th International Telecommunications Network Strategy and Planning Symposium (Networks)*, Montreal, QC, 2016, pp. 150-157, doi: 10.1109/NETWKS.2016.7751168.

Pondicherry University



The Vice-Chancellor and the Executive Council of the Pondicherry University, on the recommendations of the duly appointed Board of Examiners, hereby declare that

VIJAYARAM. B.

has been admitted to the Degree of

Bachelor of Technology

in Branch **IV - COMPUTER SCIENCE & ENGINEERING**

and placed in

FIRST

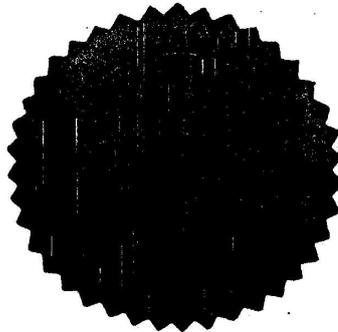
Class at the Examination

held in **MAY 2004.**

He / She was a bonafide student of

SRI MANAKULA VINAYAGAR ENGINEERING COLLEGE.

Given under the Seal of the University



Pondicherry

Dated **21 JAN 2006**

A. Bhaknagar
Vice-Chancellor

S. Sengavathi
Registrar

Serial No.: C13 07/13317

Register No.: CS0524

Pondicherry University



The Vice-Chancellor and the Executive Council of the Pondicherry University, on the recommendations of the duly appointed Board of Examiners, hereby declare that

VIJAYARAM, B.

has been admitted to the Degree of

MASTER OF TECHNOLOGY

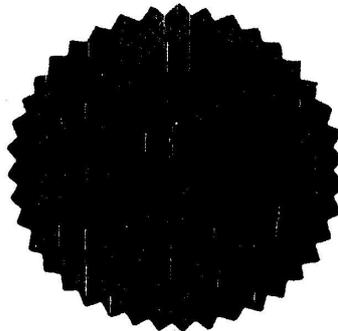
in Branch: DISTRIBUTED COMPUTING SYSTEM

and placed in FIRST CLASS at the Examination

held in MAY 2007. He / She was a bonafide student of

PONDICHERRY ENGINEERING COLLEGE.

Given under the Seal of the University



S. S. Srinivasan
Registrar

Puducherry
Date 11 MAR 2009

A. A. Maveer
Vice-Chancellor



PONDICHERY ENGINEERING COLLEGE

(AUTONOMOUS STATUS FOR ALL POST GRADUATE PROGRAMMES)
PILLAICHAVADI, PONDICHERY - 605 014
AFFILIATED TO PONDICHERY UNIVERSITY

8800

STUDENT GRADE REPORT

NAME OF THE CANDIDATE		REGN. NUMBER	SEMESTER	MONTH & YEAR	
VIJAYARAM, B.		CSC024	FIRST	DEC 2005	
PROGRAMME :	M.TECH	SPECIALISATION : DISTRIBUTED COMPUTING SYSTEMS			
SUB CODE	SUBJECT	DEPT	CORSELEC	CREDIT	GRADE
CS901	DESIGN OF OPERATING SYSTEMS	CS	CORE	4	A
CS902	HIGH PERFORMANCE COMPUTING	CS	CORE	4	D
CS903	SOFTWARE ARCHITECTURE	CS	CORE	4	D
CS904	HIGH SPEED NETWORKS	CS	CORE	4	D
CS930	REAL TIME COMPUTING AND COMMUNICATIONS	CS	ELEC	3	D
CS932	ADVANCES IN SOFTWARE ENGINEERING	CS	ELEC	3	B
CS907	ADVANCED SOFTWARE LABORATORY	CS	CORE	2	C
END OF THE STATEMENT					

TOTAL CREDITS IN THIS SEMESTER : 24
 TOTAL CREDITS TILL THIS SEMESTER : 24
 TOTAL CREDITS FOR THIS COURSE : 68

GPA : 6.93
 CGPA : 6.93



ANY CORRECTION IS INVALID

15 DEC 2006

SCHOLASTIC STATUS : PASS

CHAIRMAN
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PRINCIPAL
PONDICHERY ENGG. COLLEGE



PONDICHERY ENGINEERING COLLEGE

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STUDENT GRADE REPORT

NAME OF THE CANDIDATE		REGN. NUMBER	SEMESTER	MONTH & YEAR	
VIJAYARAM, B.		CSC024	SECOND	JUN 2006	
PROGRAMME :	M.TECH	SPECIALISATION : DISTRIBUTED COMPUTING SYSTEMS			
SUB CODE	SUBJECT	DEPT	CORSELEC	CREDIT	GRADE
CS906	ADVANCES IN DATABASES	CS	CORE	4	C
CS905	NETWORK MANAGEMENT AND SECURITY	CS	CORE	4	D
CS926	DATA COMPRESSION	CS	ELEC	3	C
CS931	OPTICAL COMMUNICATION NETWORKS	CS	ELEC	3	D
CS933	SOFTWARE REENGINEERING	CS	ELEC	3	D
CS935	MOBILE COMMUNICATION NETWORKS	CS	ELEC	3	D
END OF THE STATEMENT					

TOTAL CREDITS IN THIS SEMESTER : 20
 TOTAL CREDITS TILL THIS SEMESTER : 44
 TOTAL CREDITS FOR THIS COURSE : 68

GPA : 6.35
 CGPA : 6.61



ANY CORRECTION IS INVALID

131 JAN 2007

SCHOLASTIC STATUS : PASS

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POSTGRADUATE PROGRAMMES

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PONDICHERY ENGINEERING COLLEGE

(AUTONOMOUS STATUS FOR ALL POST GRADUATE PROGRAMMES)
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8007

STUDENT GRADE REPORT

NAME OF THE CANDIDATE		REGN. NUMBER	SEMESTER	MONTH & YEAR	
VIJAYARAM, B.		CS0524	THIRD	DEC 2006	
PROGRAMME	M.TECH	SPECIALISATION: DISTRIBUTED COMPUTING SYSTEMS			
SUB. CODE	SUBJECT	DEPT.	CORE/LEC	CREDIT	GRADE
CS909	DISSERTATION PROJECT PHASE-I	CS	CORE	9	B
CS908	SEMINAR	CS	CORE	3	B
END OF THE STATEMENT					

TOTAL CREDITS IN THIS SEMESTER: 12
 TOTAL CREDITS TILL THIS SEMESTER: 56
 MINIMUM CREDITS FOR THIS COURSE: 66

GPA: 8.00
 CGPA: 6.91



21 MAR 2007

REVISION IS INVALID

SCHOLASTIC STATUS: PASS

S. S. Sankaranarayanan
CHAIRMAN
POSTGRADUATE PROGRAMMES

S. S. Sankaranarayanan
PRINCIPAL
PONDICHERY ENGG. COLLEGE



PONDICHERY ENGINEERING COLLEGE

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9369

STUDENT GRADE REPORT

NAME OF THE CANDIDATE		REGN. NUMBER	SEMESTER	MONTH & YEAR	
VIJAYARAM, B.		CS0524	FOURTH	JUN 2007	
PROGRAMME	M.TECH	SPECIALISATION: DISTRIBUTED COMPUTING SYSTEMS			
SUB. CODE	SUBJECT	DEPT.	CORE/LEC	CREDIT	GRADE
CS910	DISSERTATION PROJECT PHASE-II	CS	CORE	12	C
END OF THE STATEMENT					

TOTAL CREDITS IN THIS SEMESTER: 12
 TOTAL CREDITS TILL THIS SEMESTER: 66
 MINIMUM CREDITS FOR THIS COURSE: 68

GPA: 7.00
 CGPA: 6.92



26 JUL 2007

REVISION IS INVALID

SCHOLASTIC STATUS: PASS

S. S. Sankaranarayanan
CHAIRMAN
POSTGRADUATE PROGRAMMES

S. S. Sankaranarayanan
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Sorry I don't have College Transfer Certificate.

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Feb 23, 2010

Mr. VIJAYARAM BOOPALAN
Emp. Code No. 40183154
HCL Technologies Limited
CHENNAI

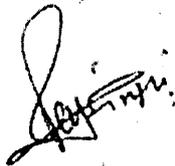
Sub:Relieving Letter

Dear Vijayaram Boopalan,

This is with reference to your resignation dated Dec 24, 2009.

We accept your resignation and you shall stand relieved from the services of the Company at close of business hours on Feb 23, 2010.

Wishing you all the best,



Rajender Sharma
SENIOR MANAGER - EHS



HCL



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www.infosys.com

HRD/RELVLTR/14-15/144217

July 23, 2014

Mr. Vijayaram Boopalan
Employee No. 144217

Dear Vijayaram,

With reference to your decision to resign from Infosys Limited ("Company" hereafter) and your resignation letter dated May 30, 2014, we are in acceptance of the same and you are relieved of your duties and responsibilities from the closing hours of July 18, 2014.

Your service record is as follows:

Name	Vijayaram Boopalan
Last Role Designation	Technology Lead
Last Role	Technology Lead
Date of Joining	March 01, 2010
Date of Leaving	July 18, 2014

We draw your attention to your continuing obligation of confidentiality with respect to any proprietary and confidential information of the Company that you may have had access to during the course of your employment.

Thank you for your contribution to Infosys and wishing you the best!

For Infosys Limited

Shamita Chatterjee
Vice President - HRD





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16 July 2019

Vijayaram Boopalan
PID: 232397
Last Designation: Technology Specialist

Sub: Relieving from the services of Com Dev Services India Private Limited

Dear Vijayaram Boopalan,

This has reference to your resignation letter dated 10th June 2019.

We acknowledge and appreciate the contributions that you have made to the organization from 28th July 2014 * (Input joining date of HON) with the last held designation Technology Specialist. You will be relieved from the services of Com Dev Services India Private Limited ("Resideo") effective close of working hours 28th June 2019.

During your employment with Resideo you had access to a considerable amount of information that is not generally known outside of Resideo. Said information may have included but not limited to business and development plans, technical data such as designs, specifications or algorithms, unpublished financial information such as orders, costs or charge rates, and business practices and procedures as well as personnel and organizational data. It may have been disclosed to you orally or in writing or may be contained in a Resideo product or a third party may have disclosed it to Resideo under a non-disclosure agreement by virtue of which you may had access to such third-party information. Resideo considers all of such information, and any other information that gives Resideo a competitive advantage over others who do not know it as confidential and proprietary irrespective of whether it was specifically marked as such or not.

*Joining date of the organization includes tenure served in Honeywell, prior to the Spinoff of Resideo, if applicable.

DocuSigned by:
Vijayaram Boopalan
270752496470AC1
July 16, 2019



Further, all inventions and copyrightable works (including software) relating to Resideo's business that you created, conceived or reduced to practice alone or with others while you were an employee are the property of Resideo. As an employee you have agreed to disclose and assign all such inventions to Resideo and to cooperate with Resideo in any legal formalities necessary to secure those rights, at Resideo's expense. Similarly, all documents and materials that were furnished to you as an employee, as well as all records, documents and materials that you created as an employee, including laboratory notebooks, remain the property of Resideo. If you should later discover any such items or copies in your possession that were overlooked, we ask that you forward them to Resideo promptly.

While we naturally assume that you intend to fulfill all of your obligations to Resideo faithfully, we thought it best to send this reminder to avoid any possible misunderstandings.

On behalf of Resideo, I'd like to thank you for your service and wish you every success in your future endeavors.

Very truly yours,

For Com Dev Services India Private Limited

A handwritten signature in blue ink that reads 'N. Sandhya'.

Sandhya Venkatanarayana
Head- Business HR

For any verification on the above details, please email Humanresources@resideo.com

DocuSigned by
A handwritten signature in blue ink that reads 'Vijayaraj Boopalan'.
27C91A884F0A25
July 16, 2019

Honeywell Technology Solutions Lab Pvt. Ltd.
CIN: U72200KA1994FTC016379
Survey no. 19/2, Devarabisanahalli village,
Vathur Hobli, Bengaluru East Taluk
Bengaluru-560 103, INDIA.
Tel: +91-80-26588360/41197222
Fax: +91-80-26584750
Email: HTSL-Communication@honeywell.com
Website: www.honeywell.com

LETTER OF APPOINTMENT

24 October 2019

Vijayaram Boopalan
Doomo:3, Floorno:3,
Aparna Paradise Phase - 2,
Parthasarathy Street, SS Colony,
Madurai - 625016, Tamil Nadu, India

Dear Vijayaram,

Honeywell's vision is to be one of the world's premier companies, distinctive and successful in everything we do. Our primary goal is to exceed our customer expectations by delivering competitive, quality products and services on time, every time.

This is an aggressive goal, which can only be attained by recruiting and developing a talented workforce. Honeywell wants individuals, who bring a diverse perspective to our business challenges, yet share our common behaviours: Have a Passion for Winning, Be a Zealot for Growth, Think Big...Then Make it happen, Act with Urgency, Be Courageous, Go Beyond, Inspire Greatness and Become your Best.

Further to your recent interview interaction with Honeywell, we are delighted to extend this offer of employment to you. This offer is conditional on (i) satisfactory reference check of all qualifications and the accuracy of the employment history provided by you; (ii) successful completion and passing the pre employment drug tests conducted by Honeywell or any company designated by Honeywell to conduct the same;(iii) the acceptance of the terms and conditions of your assignment as set forth below including the attachments that are incorporated by reference "offer" and (iv) your obtaining the necessary work or employment passes or permits from the relevant authorities in India to work in India, if applicable. The term "Company" below shall refer to the hiring entity and the term "Honeywell" to its parent entity and/or Honeywell International Inc, its predecessors, designees and successors and its past, present and future operating companies, divisions, subsidiaries, affiliates and other business units.

General Conditions

- | | |
|------------------------------------|---|
| 1. Position | Technology Specialist |
| 2. BU/Department | HTS - EHBT |
| 3. Manager | You will report to such Manager who will be assigned by Honeywell as your supervisor from time to time. |
| 4. Date of Employment Commencement | 29 October 2019 |
| 5. Band | 3 |

⁰⁸
[Signature]

⁰⁸
[Signature]



Vijayaram



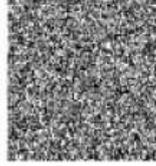
இந்திய தனிப்பட்ட அடையாள ஆணைய அமைப்பு

இந்திய அரசாங்கம்
Unique Identification Authority of India
Government of India

பதிவேட்டு எண் / Enrolment No.: 2192/50496/03094

To
விஜயரம் பூபால்
Vijayaram Boopalan
S/O,Boopalan
6
Govindaraj Nagar Ext
Murungapakkam
Near Mother Theresa School
Mudaliarpet
Puducherry Puducherry • 605004
8939653833

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QR Code with Photo: 300920210



உங்கள் ஆதார் எண் / Your Aadhaar No. :

8430 0135 0476

VID : 9106 2656 3529 4680

எனது ஆதார். எனது அடையாளம்



இந்திய அரசாங்கம்
Government of India



விஜயரம் பூபால்
Vijayaram Boopalan
இந்த நாள் DOB: 28/08/1983
ஆண் / MALE

8430 0135 0476

VID : 9106 2656 3529 4680

எனது ஆதார். எனது அடையாளம்



தகவல்

- ஆதார் அடையாளத்திற்கான சான்று, குடியரிமைக்கு ஆவல், அடையாள சான்ற ஆள்வையி ஆதர்டிகேஷன் மூலமாக பெறவும்.
- இது எலக்ட்ரானிக் செயல்முறை மூலம் தயாரிக்கப்பட்ட கடிதமாகும்.

INFORMATION

- Aadhaar is a proof of identity, not of citizenship.
- To establish identity, authenticate online.
- This is electronically generated letter,

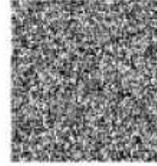
- ஆதார் நாடு முழுவதிலும் செல்லுபடியாகும்.
- வருங்காலத்தில் அரசு மற்றும் அரசு சாரா சேவைகளை பயன்படுத்திக் கொள்ள ஆதார் உதவிகரமாக இருக்கும்.
- Aadhaar is valid throughout the country.
- Aadhaar will be helpful in availing Government and Non-Government services in future.



இந்திய தனிப்பட்ட அடையாள ஆணைய அமைப்பு
Unique Identification Authority of India

மூலம்: பூபால், 6, கோவிந்தராஜ் நகர் இலாப்டி, மதர் தீரஸ் பள்ளி அருகில், முருங்கப்பக்கம், முதுலார்பேட்டை, புதுச்சேரி, புதுச்சேரி - 605004

Address: S/O,Boopalan, 6, Govindaraj Nagar Ext, Near Mother Theresa School, Murungapakkam, Mudaliarpet, Puducherry, Puducherry - 605004



8430 0135 0476

VID : 9106 2656 3529 4680

Vijayaram

GOVERNMENT OF PONDICHERRY

REVENUE DEPARTMENT

No/1541/MF/POP/05
Pondicherry Taluk Office

MOST BACKWARD CLASS CERTIFICATE

This is to certify that Thiru/Tmt./Selvi Vijayarani
son/wife/daughter of B. Palani
residing at Pondicherry
in the Union Territory of Pondicherry
belongs to Venniar which is recognised as a "Most Backward Class"
in the Union Territory of Pondicherry vide Serial No. 2(4) of the Annexure
to the Notification issued in G.O.Ms. No. 27/2004-Wel.(SW-V), dated 14-7-2004
of the Chief Secretariat (Welfare), Government of Pondicherry and published
in No. 37 dated 3/8/04 of the Official Gazette of
Pondicherry.

2. Thiru/Tmt./Selvi Vijayarani and
his/her family ordinarily reside(s) in the above-mentioned place.

3. This certificate is issued for the purpose of availing MBC reservation
in Educational Institutions and in Socio-Economic Benefits Implemented by various
Governmental Departments of this Union Territory Administration.

Date: 29/6/05



N. Devarasu
29/6/05
Tahsildar/Deputy Tahsildar-cum-
Executive Magistrate.
N. DEVARASU
Deputy Tahsildar-cum-Executive Magistrate,
Survey Department, Pondicherry.

Taluk/Sub-Taluk



Honeywell Technology Solutions Lab Pvt. Ltd.

Survey No. 96 & 97, Boganahalli Village,
Survey No. 72/2 & 72/5, Doddakannahalli Village,
Varthur Hobli, Bengaluru 560 103
Tel : +91 80 2658 8360
Fax No : +91 80 2658 4750
CIN No : U72200KA1994FTC016379
HTS-Communication@honeywell.com
www.honeywell.com

TO WHOMSOEVER IT MAY CONCERN

Certified that Mr. Vijayaram Boopalan is employed as Sr Advanced Software Engr. in the Honeywell Building Technology (Department/Division Name) of Honeywell Technology Solutions Pvt. Ltd., (Institution/Industry Name).

We have no objection in forwarding his/her application for the Ph.D. Research Programme.

FOR PART TIME:

The candidate will be permitted to undertake part time study in the University/College and will be allowed to be present for discussions with the supervisor, attending course works, conduct of experiments and participations in seminars and related presentations. Further the required facilities at our organization will also be provided to the candidate for doing research.

For Honeywell Technology Solutions Lab Pvt. Ltd.

DocuSigned by:

EF9EB724477F40D...
Maheswaran Samuthiram

Software Eng Manager