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TABLE OF CONTENTS

MESSAGE FROM GENERAL CHAIR	iii
ORGANIZING COMMITTEE	iv
ISITIA 2019 TECHNICAL PROGRAM COMMITTEE	v
TABLE OF CONTENTS	vii
KEYNOTE LECTURES	
Prof. Ryohei Kanzaki	xvi
Assoc. Prof. Dr. Supavadee Aramvith	xvii
Assoc. Prof. Dr. Tara Julia Hamilton	xviii
Dr. Muhammad Rivai	xix
Nicolas Husny Tjioe, M.Sc.	xx
TECHNICAL PAPERS	
Telecommunications and Networking	
Circular Polarization 5.5 GHz Double Square Margin Antenna in the Metal Framed Smartphone for SIL Wireless Sensor	1
<i>Irfan Mujahidin; Aries Boedi Setiawan; Dwi Arman Prasetya</i>	
Capacity Improvement Factor of HF Multi-Mode Skywave MIMO Channels	7
<i>Teguh Imam Suharto; Gamantyo Hendrantoro; Achmad Mauludiyanto; Umai Sarah; Roberto Corputty; Muriani Muriani</i>	
Parameter study of coplanar vivaldi antenna feeding structure	13
<i>Efrilia Marifatul Khusna; Eko Setijadi; Gamantyo Hendrantoro</i>	
A Modified Genetic Algorithm for Resource Allocation in Cognitive Radio Networks in the Presence of Primary Users	19
<i>Niki Robbi; I Wayan Mustika; Widy Widyanawan</i>	
IBR-DTN To Solve Communication Problem On Post-Disaster Rescue Mission	24
<i>Muhammad Fauzan; Tito Waluyo Purboyo; Casi Setianingsih</i>	
Performance Analysis of Ad-Hoc On-Demand Distance Vector (AODV) and Dynamic Source Routing (DSR) Routing Protocols During Data Broadcast Storm Problem in Wireless Ad Hoc Network	29
<i>Ida Nurcahyani; Faritz Laksono</i>	
Signal Processing	
Asphalt Pavement Pothole Detection using Deep learning method based on YOLO Neural Network	35
<i>Ernin Ukhwah; Yoyon Suprpto; Eko Mulyanto Yuniarno</i>	

Sensors and Instrumentation

Horizontal Scanning Method by Drone Mounted Photodiode Array for Runway Edge Light Photometry 41
Daniel Steven Doxazo Sitompul; Fakhri Surya; Fakhri Suhandi; Hasballah Zakaria

Comparative Study of Burst And Beams Types Ultrasonic Sensor For Distance Measurements 46
Purwadi Agus Darwito; Murry Raditya; Halimatus Sa'diyah; Arviandi Cikadiarta; Aditya Wimansyah

QCM Coating With rGO Material as a Platform Developing Piezoelectric Biosensor 52
Dody Susilo; Totok Mujiono; Darminto Darminto

Soft Sensor Design of Solar Irradiance Using Multiple Linear Regression 56
Muhammad Khamim Asy'ari; Ali Musyafa'; Ronny Noriyati; Katherin Indriawati

Classification of the Quality of Milk Using Spectrophotometer System Based on Raspberry Pi 61
Fajar Budiman; Muhammad Rivai; Muhammad Gemintang; Suwito Suwito; Harris Pirngadi

Monitoring and Control System for Ammonia and pH Levels for Fish Cultivation Implemented on Raspberry Pi 3B 68
Fajar Budiman; Muhammad Rivai; Muhammad Nugroho

Fuzzy Logic-Based Wet Scrubber to Control Air Pollutant 74
Bima Romadhon Parada Dian Palevi; Muhammad Rivai; Djoko Purwanto

Implementation of Gas and Sound Sensors on Temperature Control of Coffee Roaster Using Fuzzy Logic Method 80
Agus Hayatal Falah; Muhammad Rivai; Djoko Purwanto

Robotics and Automation

Development of Unmanned Aerial Vehicle (UAV) for Dropping Object Accurately Based on Global Positioning System 86
Ronny Mardiyanto

Ladder Diagram Design Based On Change Signal Method For Crude Palm Oil Process 91
Eka Iskandar; Mochammad Rameli; Andhiko Palito F

Leader Follower Navigation System based on Pedestrian Dead Reckoning for Mobile Robot Navigation 96
Muhammad Farih; Mochammad Sahal; Rusdhianto Effendi Abdul Kadir

Power and Energy Systems

Optimizing Tie Switches Allocation and Sizing Distributed Generation (DG) based on Maximize Loadability Simultaneously using HPSO Algorithm 102

<i>Darma Arif Wicaksono; Ontoseno Penangsang; Rony Seto Wibowo; Dimas Fajar Uman Putra; Ni Aryani</i>	
MPPT Based on Modified Incremental Conductance Algorithm for Solar Powered UAV <i>Heri Suryoatmojo</i>	108
A Comparative Study of Maximum Power Point Tracking Algorithms for Wind Energy Systems in Giligenting Island <i>Soedibyo Soedibyo; Ahmad Firyal Adila; Sjamsjul Anam; Mochamad Ashari</i>	114
Design of Single-Forward Type Charger Using SiC MOSFET for Pulsed Power Generator <i>Ahmad Firyal Adila; Heri Suryoatmojo; Mochamad Ashari; Takashi Sakugawa</i>	120
Optimal Placement and Sizing Distributed Generation (DG) Considering Energy Storage Using ABC-QP Algorithm <i>Luthfia Fajariyanti; Rony Seto Wibowo; Ontoseno Penangsang; Dimas Fajar Uman Putra; Ni Aryani</i>	126
Security Constrained Unit Commitment Considering Ramp Rate and Transmission Line Losses Using Binary Particle Swarm Optimization Based on IEEE 30 Bus System <i>Ni Aryani; Dimas Fajar Uman Putra; Elpha Aulia Arifin; A. Saad Daroini</i>	132
Design and Implementation of Three-Phase Grid-Connected Inverter for PV System <i>Nur Rohmat Hadianto; Mustaghfiri Mustaghfiri; Fifi Hesty; Joke Pratilastiarso; Erik Tridianto</i>	138
Application of High Gain Zeta Converter For Photovoltaic System <i>Heri Suryoatmojo</i>	144
Determining Critical Clearing Time Based on Critical Trajectory Method using Unbalance Fault <i>Ardyono Priyadi; Talitha Puspita Sari; Wahyu Dwi Saputro; Naoto Yorino; Mauridhi Hery Purnomo</i>	150
Modelling of Distribution Compensator for Inrush Current of Medium Voltage Induction Motor in an Air Separation Plant Power Systems <i>Indra Hermawan; Mochamad Ashari</i>	155
The Design of RBMP Technique to Limit The Fault Current and Voltage Dip in Medium Voltage Electrical System Application <i>Margo Pujiantara; Vincentius Raki Mahindara; Bintha Fachrurriza; Ardyono Priyadi; Mauridhi Hery Purnomo</i>	159
Harmonic Effect For Voltage Stability Condition In Radial Distribution System <i>Novian Patria Uman putra; Adi Soeprijanto; Ni Aryani; Dimas Fajar Uman Putra</i>	165

Optimal Planning of Solar PV Using Simple Model for New Feed-in Tariff in Indonesia <i>Kharisma Bani Adam; Hajime Miyauchi</i>	171
Controlling Line Power Flow in JAMALI (Jawa-Madura-Bali) System Using STATCOM <i>Anugerah Akbar Setiyawan; Ontoseno Penangsang; Ni Aryani</i>	177
Design and Implementation of DC-DC Bidirectional Cuk Converter with Average Current Mode Control for Lead Acid Battery Testing <i>Irham Izzatur Rahman; Dedet Riawan; Mochamad Ashari</i>	183
Power Swing Phenomenon on Jawa Bali 500 kV Backbone and Its Mitigation <i>Ontoseno Penangsang; Ni Aryani; Restu Maulana Azmi; Gracia Manuella</i>	189
Security Constrained Unit Commitment Considering Transmission Capacity and Loss With Non-Smooth Generation Cost Function Using Binary Particle Swarm Optimization (BPSO) Algorithm <i>Ni Aryani; Rony Seto Wibowo; Dimas Fajar Uman Putra; A. Saad Daroini; Elpha Aulia Arifin</i>	195
Microelectronics and VLSI	
Implementation of cross correlation with stochastic computation in FPGA <i>Rifqi Yunus Pratama; Thibault Pichel; Astria Nur Irfansyah; Fajar Budiman</i>	201
Information Technology	
Next Generation Firewall for Improving Security in Companies and IOT Network <i>Benfano Soewito</i>	205
Clustering on Multidimensional Poverty Data using PAM and K-prototypes Algorithm (Case Study: Jambi Province 2017) <i>Aris Wijayanto; Yoyon Suprpto; Diah Wulandari</i>	210
Implementation of Cryptography Module Security Certification Based on SNI ISO/IEC 19790:2012 - Security Requirements For Cryptography Module <i>Yasril Andriawan; Ival Tirta</i>	216
Maturity Level Analysis of Governance and Integration IT of Simkeuda in Pamekasan Regency Using COBIT 4.1 <i>Novis Prasetyawan; E Endroyono; Supeno Susiki</i>	222
Authentication of Printed Document Using Quick Response (QR) Code <i>Ahmad Tasyrif Arief; Iwan Wirawan; Yoyon Suprpto</i>	228
Classification of Aircraft Inspection Result Using K-Nearest Neighbors <i>Nurhadiyanto Nurhadiyanto; Supeno Susiki; Eko Setijadi</i>	234
Vehicle Distance Measurement Tuning using Haversine and Micro-Segmentation <i>Aghus Sofwan; Yosua Alvin Adi Soetrisno; Eko Handoyo; M Arfan; Natalia Ramadhani; Amiko Rahmayani</i>	239

Analysis of Secure Bit Rate for Quantum Key Distribution based on EDU-QCRY1 <i>Dedy Septono Putranto; Damayani Suyitno; Haykal Octa Asmar; Rini Wardhani; Mohamad Syahrul; Dion Ogi</i>	244
Clinical decision support system for typhoid fever disease using classification techniques <i>Boby Andrianto; Yoyon Suprpto; Istas Pratomo; Ika Irawati</i>	248
High Voltage Engineering	
Wavelet Transformation Selection for Detection of Ferroresonance Behaviour <i>I Made Yulistya Negara; Dimas Anton Asfani; I Gusti Satriyadi; Daniar Fahmi; Bagas Kuntala Aji; Verdiansyah Verdiansyah</i>	253
Floating Metal Particle Motion Characteristics with Shape and Size Variation in the Oil Insulation Under DC Voltage <i>Daniar Fahmi; I Made Yulistya Negara; Dimas Anton Asfani; I Gusti Satriyadi; Tasha Deliana; Juan Christian Soebagio</i>	259
Low-Voltage Arcing Detection on Non-Linear Load with Total Harmonic Distortion and Power Factor Variations <i>Dimas Anton Asfani; Daniar Fahmi; I Made Yulistya Negara; I Gusti Satriyadi; Jefri Setyadi; Made Yudha Pranadiksa Giri</i>	265
Control Systems	
Modeling and Simulation of Independent Speed Steering Control for Front In-wheel in EV Using BLDC Motor in MATLAB GUI <i>Chhith Chhlonh; Dedet Riawan; Heri Suryoatmojo</i>	270
Transition Control on Hybrid Unmanned Aerial Vehicles (UAV) using Altitude Change <i>Imroatul Hudati; Achmad Jazidie; Rusdhianto Efendi Abdul Kadir</i>	276
Path Planning for Differential Drive Mobile Robot to Avoid Static Obstacles Collision using Modified Crossover Genetic Algorithm <i>Nia Saputri Utami; Achmad Jazidie; Rusdhianto Efendi Abdul Kadir</i>	282
Computer Engineering	
SIFT and ICP in Multi-View based Point Clouds Registration for Indoor and Outdoor Scene Reconstruction <i>Muhammad Imanullah; Eko Mulyanto Yuniarno; Surya Sumpeno</i>	288
The IMU and Bend Sensor as a Pointing Device and Click Method <i>Romy Budhi Widodo; Agustinus Haryasena; Hendry Setiawan; Mochamad Subianto; Paulus Irawan; Didik Suharso; Iskandar Iskandar; Ardiansyah Ardiansyah; Ari Lusiandri</i>	294
Blind People Guidance System using Stereo Camera <i>Ichsan Pratama Adi; Hendra Kusuma; Muhammad Attamimi</i>	298

Biomedical Engineering

Estimation of Nigrescens Palm Oil Ripeness using Contrast and Skewness from 680 nm Image 304

Agung W. Setiawan; Donny Danudirdjo; Alfie Rizky Ananda

Panoramic of Image Reconstruction Based on Geospatial Data Using SIFT (Scale Invariant Feature Transform) 308

Adi Hermansyah; Eko Mulyanto Yuniarno; Supeno Mardi Susiki Nugroho; Arif Nugroho; Arief Kurniawan

Seizure Type Detection in Epileptic EEG Signal using Empirical Mode Decomposition and Support Vector Machine 314

Inung Wijayanto; Rudy Hartanto; Hanung Adi Nugroho; Bondhan Winduratna

Automatic Detection of Fetal Head using Haar Cascade and Fit Ellipse 320

Putri Nadiyah; Riyanto Sigit; Heny Yuniarti; Noor Rofiqah; Qurina Firdaus

EEG Visualization for Cybersickness Detection During Playing 3D Video Games 325

Khaitami Khaitami; Adhi D Wibawa; Supeno Susiki; Alfi Khoirunnisaa

EEG-based motion task for healthy subjects using time domain feature extraction: A preliminary study for finding parameter for stroke rehabilitation monitoring 331

Dwi Rahmat Mulyanto; Evi Pane; Wardah Rahmatul Islamiyah; Mauridhi Hery Purnomo; Adhi D Wibawa

Identifying EEG Parameters to Monitor Stroke Rehabilitation using Individual Analysis 337

Hendra Setiawan; Wardah Rahmatul Islamiyah; Mauridhi Hery Purnomo; Adhi D Wibawa

The Effect of Sampling Rate on the Extraction of VEP Features Using Wavelet Transform 343

Hasballah Zakaria; Maula Ahmad

Stress Diagnostic System and Digital Medical Record Based Internet of Things 348

Rachmad Setiawan; Fajar Budiman; Wahyu Basori

Wavelet-Based Respiratory Rate Estimation Using Electrocardiogram 354

Anita Miftahul Maghfiroh; Achmad Arifin; Tri Sardjono

Artificial Intelligence and Machine Learning Applications

Wood Strength Classification Based on RGB Color and Image Texture Using KNN Method 360

Okta Dhirga Sukrisdyanto; I Ketut Pumama; Supeno Nugroho

Clustering of female avatar Face features consumers choice using KMeans and SOM algorithm 366

Citra Dewi Megawati, CM; Eko Mulyanto Yuniarno; Supeno Susiki

Pre-Collision Warning and Recommendation System for Assistant Driver using Least Square Support Vector Machine and Fuzzy Logic <i>Alifia Puspaningrum; Adi Suheryadi; A Sumarudin</i>	371
Preliminary Study of Multi Convolution Neural Network-Based Model To Identify Pills Image Using Classification Rules <i>Windra Swastika; Kestrilia Prilianti; Andrian Stefanus; Hendry Setiawan; Afif Zuhri Arfianto; Ari Wibawa; Mohammad Basuki Rahmat; Edy Setiawan</i>	376
Combining SentiStrength and Multilayer Perceptron in Twitter Sentiment Classification <i>Eko Yudhi Prastowo; E Endroyono; Eko Mulyanto Yuniarno</i>	381
Forecasting Sunspot Numbers Using Fuzzy Time Series Markov Chain Model As Flare Identification <i>Dian Candra Rini Novitasari; Nurul Ardhiyah; Nanang Widodo</i>	387
Water Pipe Leak Detection using the k-Nearest Neighbor Method <i>Abdul Rojik; Astria Nur Irfansyah; E Endroyono</i>	393
Village Classification based on Geographic Difficulties using Backpropagation Neural Network Algorithm (Case Study: Village Potential of Sumenep Regency) <i>Heru Setiono; Supeno Susiki; Eko Mulyanto Yuniarno</i>	399
Personality Classification from Online Handwritten Signature using k-Nearest Neighbor <i>Harris Teguh Laga; Evi Pane; Adhi D Wibawa; Mauridhi Hery Purnomo</i>	404
Analysis of Students Ability Assessment Based on Bloom's Taxonomy Using Fuzzy Signatures <i>Eryca Dwi Huzaini R; Umi Laili Yuhana; Eko Setijadi; Mauridhi Hery Purnomo</i>	410
Instance-Aware Semantic Segmentation for Food Calorie Estimation using Mask R-CNN <i>Reza Dea Yogaswara; Eko Mulyanto Yuniarno; Adhi Dharma Wibawa</i>	416
Vehicle Brands and Types Detection Using Mask R-CNN <i>Mohammad Wahyudi Nafi'i; Eko Mulyanto Yuniarno; Achmad Affandi</i>	422
Community Feedback Analysis Using Latent Semantic Analysis (LSA) To Support Smart Government <i>Zakky Sanjifa; Surya Sumpeno; Yoyon Suprpto</i>	428
Development of Indonesian Speech Recognition with Deep Neural Network for Robotic Command <i>Citta Anindya; Djoko Purwanto; Desy Iba Ricoida</i>	434
Regulation Document Search Based on Themes using Cosine Similarity and Naive Bayes <i>Gayuh Suwiatmaja; Surya Sumpeno; I Ketut Eddy Purnama</i>	439

Implementation of Voice Recognition in Disaster Victim Detection System Using Hidden Markov Model (HMM) Method <i>Ferry Alifani; Tito Waluyo Purboyo; Casi Setianingsih</i>	445
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Abstract— Personal medicine is very important for those who have special health problems. Having several types of pills can make it hard for people to remember every pill especially aged citizen who easily forget his or her own medication. Another problem often encountered is the difficulty of recognizing the drug pills whose labels or the packaging are damaged and hard to read. This research, we developed a multi convolutional neural network (CNN) model to identify pills using classification rules. The idea of using multi CNN model is that almost all type of pills have three main identifiers, namely color, shape and imprint. Three CNNs model are developed to represent each identifier. The number of data collected is 24.000 images, which 95% of the data is used for training purpose and 5% is used for data test. The results of each CNN model is processed with some predefined rules to generate the classes of pills. From the results of different CNN architectures, number of epochs, optimizers and input size experiments, LeNet architecture with input size 64x64 pixels and Adadelata optimization shows the best accuracy up to 99.16%.

Keywords—convolution neural network, pill identification

I. INTRODUCTION

Self-medication is a treatment of health problems to oneself by use of medicines that are bought freely in drug stores for their own initiative without medical advice [1]. The goal of self-medication is to improve health, treat minor illnesses, and routinely treat chronic diseases after doctor's care. Meanwhile, the role of self-medication is to deal quickly and effectively with complaints that do not require medical consultation, reduce the burden of health services on limited resources and energy, and increase the affordability of people far from health services [2].

In many health problems, self-medication requires several type of medicines. Having several types of medicines (drug pills) can make it hard for people to remember every pill especially for aged citizen who easily forget his or her own medication. Another problem often encountered is the difficulty of recognizing the pills whose labels or the packaging are damaged and hard to read. Those problems can lead to mistreatment of health problem.

To minimize the risk of mistreatment caused by the difficulty of recognizing pills, it is necessary to develop a mobile-based application that is able to automatically identify pills obtained from a camera and shows information about the pills. One of the benefit of this application is during a disaster or emergency situation where pill identification is urgently required to safe patient.

A mobile based pill identification application was developed by Lee et al [3] where users only need to take pictures of pills through a smartphone camera. The recognition metho⁴s using Hu moment to recognize the shape of the drug, shape invariant feature transform (SIFT) and multi-scale local binary pattern (MBLT) descriptor to recognize the characters contained in the pill and the color histogram to recognize the color of the pill. The accuracy of this application in recognizing pills is 73.17%.

The use of Convolutional Neural Network (CNN) to identify pills was introduced by Zeng et al [4]. They developed a system to identify pills by using the Multi Convolutional Neural Network method consisting of three CNNs. Each CNN has a different task in processing shapes, colors and characters printed on pills such as Color CNN to manage color information, Gray CNN and Gradient CNN to process information on the shape and character of the pill. For the accuracy of the pill identification with only one side using single-CNN was 26.1% while using multi-CNN was 53.1%. The identification using both sides of the pill using single-CNN was 23.1% while using multi-CNN was 74.1%. To identify the pills, the authors use similarity score calculated fro³ cosine distance. Since there are three independent CNNs, similarity score is calculated as the sum of similarity score of color, gray and ⁷radient.

In this research we propose a multi-CNN method based on the three main identifier of a pill namely color (white, yellow, peach and blue), shape dan imprint (character printed on pill). To cover all three identifiers, the developed system will run three CNNs that is responsible for each identifier. The output of CNNs are then fed into a customiz²lassification rule to identify the pill. We also investigate the appropriate CNN

architecture and optimizer to obtain the most accurate identification system.

II. MATERIALS AND METHODS

A. Dataset

The first step carried out in this study was collecting drug information data through online media. There are 8 types of pill are collected consisting of four different types and colors. The drugs used in this study were Amoxicillin, Amoxicillin Trihydrate, Paracetamol, Mixagrip Flu, Decolgen, Spasmal, Sanmol, and Neozep Forte. Each drug information contains information on the name, description, shape, color, type, category, indication, dosage, usage rules, side effects, attention and methods of storing the drug. Fig. 1 shows 8 types of pill used in this study. It also shows four samples of each pill obtained in different distances and angle.

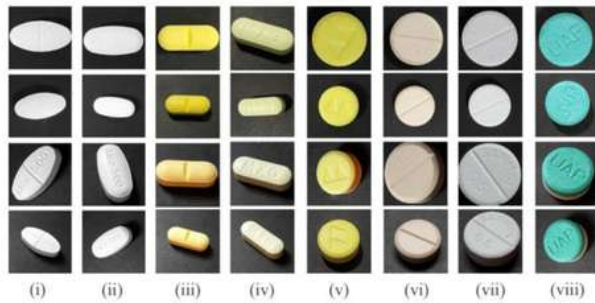


Fig. 1. (i) Amoxicillin, (ii) Amoxicillin Trihydrate, (iii) Paracetamol, (iv) Mixagrip Flu, (v) Decolgen, (vi) Spasmal, (vii) Sanmol, dan (viii) Neozep Forte

Image acquisition is done with a variety of distances, camera quality, lighting, and drug position. In this study we use 13 Mp camera resolution. To simplify the pill localization process in the image, black background colors are used in each image during the acquisition.

Obtained images are distributed for the training process and testing data. Since there are 3 main identifiers to identify pill, we use 3.000 images for each pill as data training for CNN color, 3.000 images for each pill as CNN shape, and 1.600 images for each pill as data training for CNN imprint. Data training for CNN imprint is less than data training for CNN color and CNN shape because only one-side of pill has character on the surface of the pill.

B. Image Preprocessing

The images were pre-processed first before they are trained in the CNNs. The preprocessing is divided into three parts which will be used as input for each CNN, the pre-process includes pre-processes for the shape, color and imprint of the pill image. Tabel 1 shows image preprocessing for each CNN.

TABLE I. NUMBER OF IMAGES AND PRE-PROCESSING FOR EACH CNN

CNN	# image	Pre-processing
Shape	3.192	Raw Image → Grayscale → Gaussian Blur

CNN	# image	Pre-processing
Color	3.192	Raw Image → Gaussian Blur
Imprint	1.600	Raw Image → Grayscale → Sharpening

Fig 2 shows an example of a pill that has been preprocessed for each CNN.

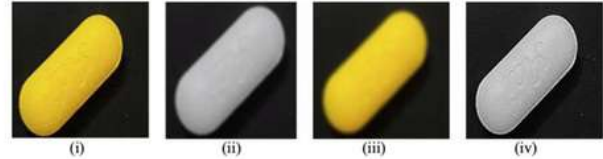


Fig. 2. (i) Original image before pre-processed; (ii) pre-processed image for CNN shape; (iii) pre-processed image for CNN color, and (iv) pre-processed image for CNN imprint

C. Classification Rules

All pre-processed images in the previous step will be resized according to the input size of each CNN architecture. Three CNNs will be used to identify 3 main characteristics of pill, namely color, shape and imprint. The output for CNN color and CNN shape are divided into 4 classes as shown in the Fig 3.



Fig. 3. (i) classification of CNN shape and (ii) classification of CNN color

Each class of CNN shape represent pill as follows:

- Class 0: Amoxicillin (0)
- Class 1: Amoxicillin Trihydrate (1)
- Class 2: Paracetamol (2), and Mixagrip Flu (3)
- Class 3: Decolgen (4), Spasmal (5), Sanmol (6), and Neozep Forte (7)

Each class of CNN color represent pill as follows:

- Class 0 (white): Neozep Forte (7), Sanmol (6), Amoxicillin Trihydrate (1), and Amoxicillin (0)
- Class 1 (yellow): Decolgen (4), Paracetamol (2), and Mixagrip Flu (3)
- Class 2 (peach): Spasmal (5)
- Class 3 (blue): Neozep Forte (7)

The output of each CNN is a percentage of the confidence level in each class. Color classification is divided into 4 classes, namely white, yellow, peach, and blue. Shape classification is divided into 4 classes while the imprint classification is divided into 15 classes as shown in Fig. 4.



Fig. 4. Output for imprint classification

Outputs from CNN shape, CNN color and CNN imprint will be combined based on a classification rules to determine the final output.

The classification rules to identify pill are as follow:

1. Look for classes that have the highest confidence level from the classification results of each CNN shape, color and imprint.
2. Match the output from CNN shape and CNN color. If the output is mismatch, then identification fails. Otherwise, keep all matching pills as potential identification.
3. Match all potential identification from previous step with selected output of CNN imprint.
4. If all pills in the potential identification mismatch with the output of CNN imprint, then identification fails. Otherwise pill successfully identified.

Using the classification rules, there are only two possible output, successfully identified or fail to identify.

D. Evaluation

Confusion matrix is used to evaluate the performance of CNN architecture and optimizer as shown in Table II.

TABLE II. CONFUSION MATRIX USED TO EVALUATE THE PERFORMANCE OF CNN

N		Predicted Class			
		C_1	C_2	...	C_n
Actual class	C_1	TP_1	$E_{C_1C_2}$	$E_{C_1C_{...}}$	$E_{C_1C_n}$
	C_2	$E_{C_2C_1}$	TP_2	$E_{C_2C_{...}}$	$E_{C_2C_n}$
	...	$E_{C_{...}C_1}$	$E_{C_{...}C_2}$	$TP_{...}$	$E_{C_{...}C_n}$
	C_n	$E_{C_nC_1}$	$E_{C_nC_2}$	$E_{C_nC_{...}}$	TP_n

where:

- TP_i : True positive for i^{th} class
- N: the number of data test
- n: number of class
- C_1-C_n : 1st-nth class
- $E_{C_iC_j}$: error recognizing class C_i being class C_j

6 Some of the metrics that are the focus of the evaluation are True Positive, False Positive, False Negative, True Negative, Accuracy, Sensitivity and Specificity (Table III).

TABLE III. METRICS USED TO MEASURE CNN PERFORMANCE

Metrics	Formula	Evaluation focus
True Positive (TP)	TP_i	Correctly identify i^{th} class (positive class)
False Positive (FP)	$\sum_{j=1}^{i-1} E_{C_jC_i} + \sum_{j=i+1}^n E_{C_jC_i}$	Incorrectly identify j^{th} class (negative class) as i^{th} class (positive class)
False Negative (FN)	$\sum_{j=1}^{i-1} E_{C_iC_j} + \sum_{j=i+1}^n E_{C_iC_j}$	Incorrectly identify i^{th} class (positive class) as j^{th} class (negative class)
True Negative (TN)	$N - (TP_i + FP_i + FN_i)$	Correctly identify negative class
Accuracy (acc)	$\frac{\sum_{i=1}^n TP_i}{N}$	Correctly identified i^{th} class ratio
5 Sensitivity (sn)	$\frac{TP_i}{TP_i + FN_i}$	True positive rate of i^{th} class
Specificity (sp)	$\frac{TN_i}{TN_i + FP_i}$	True negative rate of i^{th} class

E. Experimental Parameters

In this study, we use two types of CNN architecture to compare which architectures yield better accuracy. The following are two architecture that will be used in this study:

1. LeNet. LeNet [5] has two convolutional layers followed by max pooling and ends with two fully connected layers. The diagram of LeNet is shown in the Fig. 5.

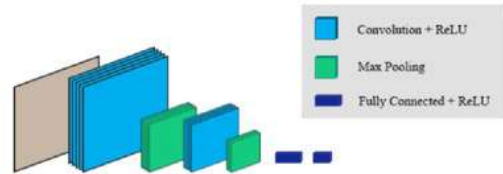


Fig. 5. LeNet Architecture

2. AlexNet. AlexNet [6] has five convolutional layers with an end to three fully connected layers. The diagram of AlexNet architecture is shown in the Fig. 6.

TABLE IX. EVALUATION RESULTS OF CNN IMPRINT FOR CLASS 8-14

Evaluation focus	Class						
	8	9	10	11	12	13	14
TP	79	79	78	70	77	80	79
TN	1119	1119	1119	1117	1122	1120	1119
FP	2	1	3	13	1	0	1
TN	0	1	0	0	0	0	1
Specificity	100%	98%	100%	100%	100%	100%	98%
Sensitivity	99%	99%	99%	98%	99%	100%	99%

As shown in Table VI-IX, the average specificity of each class is above 98%. It means that the network is able to identify each class with error less than 2%. Likewise, the average value of the specificity of each class is above 99%, which means that it can distinguish one class from another class. Overall performance of identification accuracy for LeNet and AlexNet architecture is shown in Table X.

TABLE X. IDENTIFICATION ACCURACY USING 1.200 DATA TEST

Architecture	CNN			Classification rule
	Shape	Color	Imprint	
LeNet	99.83%	99.50%	99.08%	99.16%
AlexNet	100%	99.66%	97.75%	98.75%

Using 1.200 images, the network using LeNet architecture is able to correctly identify 1.198 images for CNN shape, 1.194 images for CNN color and 1.189 images for CNN imprint. The final identification performance after implementing classification rule is able to correctly identify 1.190 images.

For AlexNet architecture with 72x72 pixels, after implementing classification rule, the network is able to correctly identify 1.185 images and fails to identify 15 images. LeNet architecture shows better performance accuracy compared to AlexNet architecture although the input size of

LeNet is 64x64 pixels. One of the contributing factors is the performance of CNN imprint is lower compared to the performance of the CNN imprint of the Lenet architecture.

IV. CONCLUSION

We have developed a multi CNN based model to identify pill image. There are three main identifiers of a pill that needs to be identified, ie shape, color and imprint. Three CNNs model are developed based on those three main identifier and a classification rule to combine the results of CNNs model are applied.

Using 1.200 data test, The highest identification accuracy 99.16% is achieved by LeNet architecture with 30 epochs, image size 64x64 pixels and uses the Adadelta optimization. The results of specificity and sensitivity in the evaluation also demonstrated the ability of the network to distinguish between the classes above 98%.

For the future work, we will apply this model in an android-based applications to identify pill image obtained from a camera.

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