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# Proceedings

## The 6<sup>th</sup> PIM International Conference

*Reconnecting the World of Coexistence  
through Business and Education*

(Online Conference)

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## Table of Contents

	Page
The 6 <sup>th</sup> PIM International Conferences	1
Conference Program	4
List of Articles	5
<b>Detail of Articles</b>	
A - Agriculture	19
B - Business	45
C - Communications	427
D - Economics	435
E - Education	501
F - Engineering and Technology	601
G - Library Arts	630
H - Management	671
<b>Appendixes</b>	
• Announcement of the Administrative Committee of The 6 <sup>th</sup> PIM International Conferences	A1
• Co-host	A11
• Peer Reviewers	A12



# List of Articles





## A-Agriculture

Code	Title	Name - Surname	Affiliation	Page
A-001	淡水养殖绿色发展评价指标体系构建 CONSTRUCTION OF EVALUATION INDEX SYSTEM FOR GREEN DEVELOPMENT OF FRESHWATER AQUACULTURE	Dayong Xu	Panyapiwat Institute of Management	19
A-002	公众情境理论视角下的农业技术推广影响因素研究----以和平县和博白县百香果密植技术为例 THE INFLUENCING FACTORS OF AGRICULTURAL TECHNOLOGY EXTENSION FROM THE PERSPECTIVE OF PUBLIC SITUATION THEORY----TAKING PASSION FRUIT DENSELY PLANTING TECHNOLOGY IN HELPING COUNTY AND BOBAI COUNTY AS AN EXAMPLE	1. Jie Wang 2. Fuhong Zhang	1 Guangdong University of Finance and Economics 2 Shandong Agriculture University	34



## B-Business

Code	Title	Name - Surname	Affiliation	Page
B-001	A COMPARISON BETWEEN GOLD, BITCOIN, AND ETHEREUM IN COVID-19 PANDEMIC	1. Tapanat Chaigosi 2. Wei Yang	Adam Smith Business School, University of Glasgow, Scotland	45
B-002	FACTORS AFFECTING ON BRAND LOYALTY OF A TELECOMMUNICATION PROVIDER IN YANGON, MYANMAR	Ngreim Hsu Wai	Ministry of Planning and Finance, Myanmar	54
B-003	HOW FINANCIAL TECHNOLOGY (FINTECH) AND REGULATORY TECHNOLOGY (REGTECH) CAN HELP BUSINESSES MANAGE THE RISK OF THE CORONAVIRUS OUTBREAKING	Tapanat Chaigosi	MSc Financial Technology School of Adam Smith Business	63
B-004	THE CORRELATION BETWEEN E-LEADERSHIP AND EMPLOYEE CREATIVITY	1. Liang Zhao 2. Jiwen Song	1 Panyapiwat Institute of Management 2 University of Leeds	66
B-005	THE IMPACT OF CORPORATE GOVERNANCE LEVEL ON THE LARGE SHAREHOLDERS' EQUITY PLEDGE SCALE AFTER M&A COMPLETION	1. Zhanyong LU 2. Guihua LU 3. Yajing Wang	1,2 Panyapiwat Institute of Management 3 Tongren Vocational and Technical College, China	77
B-006	CH4S 店体验感知对服务质量的影响研究 THE INFLUENCE OF EXPERIENCE PERCEPTION ON SERVICE QUALITY OF CH4S STORE	Fan Yang	Panyapiwat Institute of Management	92
B-007	差序氛围感知对员工知识共享私欲的影响：情绪智力的调节作用 THE INFLUENCE OF DIFFERENTIAL ATMOSPHERE PERCEPTION ON EMPLOYEES' KNOWLEDGE SHARING GREED: THE MODERATING EFFECT OF EMOTIONAL INTELLIGENCE	1. Chen Cai 2. Yu Lu	Baise College	103
B-008	大股东减持对高科技上市公司市值影响研究 THE IMPACT OF LARGE SHAREHOLDERS' SELLING ON HIGH-TECH LISTED COMPANIES' MARKET VALUE	Shanwei Lin	Panyapiwat Institute of Management	110
B-009	工匠精神对顾客公民行为的影响研究—基于中国传统手工技艺非遗产品 z 世代顾客群体的调查数据 THE INFLUENCE OF CRAFTSMAN SPIRIT ON CUSTOMER CITIZENSHIP BEHAVIOR—BASED ON THE SURVEY DATA OF GENERATION Z CUSTOMERS OF CHINESE TRADITIONAL HANDICRAFT INTANGIBLE CULTURAL HERITAGE PRODUCTS	Jie Liang	Panyapiwat Institute of Management	124



Code	Title	Name - Surname	Affiliation	Page
B-010	购物环境刺激对消费者在线冲动购买意愿影响研究——时间压力的调节作用 THE EFFECT OF SHOPPING SITUATIONAL FACTORS ON ONLINE IMPULSE PURCHASING INTENTION OF CONSUMER——TIME PRESSURE'S REGULATION	Xiaobo Lin	Panyapiwat Institute of Management	139
B-011	H 美术培训机构市场营销策略研究 MARKETING STRATEGY OF H ART TRAINING INSTITUTION	1. Bo Li 2. Zhaoqi Peng	Panyapiwat Institute of Management	156
B-012	“互联网+”背景下柳州螺蛳粉网络营销优化策略研究 OPTIMIZATION OF NETWORK MARKETING STRATEGY FOR LIUZHOU RIVER SNAILS RICE NOODLE UNDER THE BACKGROUND OF “INTERNET PLUS”	1. Lina Xie 2. Xuemei Sun	Panyapiwat Institute of Management	172
B-013	建设工程项目团队知识异质性对团队绩效的影响研究 THE IMPACT OF KNOWLEDGE HETEROGENEITY OF CONSTRUCTION PROJECT TEAM ON TEAM PERFORMANCE	Ke Hu	Panyapiwat Institute of Management	182
B-014	基于 ECSI 模型的爱依服良庆门店顾客满意度调查 INVESTIGATION ON CUSTOMER SATISFACTION SURVEY OF AIYI CLOTHING LIANGQING STORES BASED ON ECSI MODEL	1. Yalin Yang 2. Zhaomei Chi	Panyapiwat Institute of Management	192
B-015	基于供需视角的百色铝物流评价及优化路径 EVALUATION AND OPTIMIZATION PATH OF BAISE ALUMINUM LOGISTICS FROM THE PERSPECTIVE OF SUPPLY AND DEMAND	Xiaojing Wei	Panyapiwat Institute of Management	206
B-016	基于情境领导理论下的语言补习学校泰国籍中文教师的教学过程研究 THE TEACHING PROCESS OF THAI NATIVE CHINESE LANGUAGE TEACHERS FROM LANGUAGE TUITION SCHOOLS UNDER SITUATIONAL LEADERSHIP THEORY	1. Hui Wang 2. Ao Chen	Panyapiwat Institute of Management	220
B-017	基于扎根理论的正大集团雇主品牌传播效果评价研究 THE EVALUATION OF THE EMPLOYER BRAND COMMUNICATION EFFECT OF CP GROUP BASED ON GROUNDED THEORY	1. Zaiqin Yang 2. Yishu Liu	Panyapiwat Institute of Management	238
B-018	跨境电商服务能力与企业绩效的关系—以数字供应链为中介变量 THE RELATIONSHIP BETWEEN CROSS-BORDER E-COMMERCE SERVICE CAPABILITIES AND ENTERPRISE PERFORMANCE—TAKE DIGITAL SUPPLYCHAIN AS AN MEDIATING VARIABLE	1. Yuan Ji 2. Hong Yan	Panyapiwat Institute of Management	252



Code	Title	Name - Surname	Affiliation	Page
B-019	留学生对企业跨国并购的影响研究综述 THE INFLUENCE OF OVERSEAS STUDENTS ON CROSS-BORDER M&A	Hong Yu	<ul style="list-style-type: none"> <li>• Panyapiwat Institute of Management</li> <li>• Yunnan University of Finance and Economics, China</li> </ul>	264
B-020	“轻触”整合促进了技术创新吗？——来自中国企业逆向跨国并购的经验证据 DOES LIGHT-TOUCH INTEGRATION PROMOTE TECHNOLOGICAL INNOVATION? AN EMPIRICAL EVIDENCE FROM CHINESE REVERSE CROSS-BORDER M&AS	Binglun Li	Panyapiwat Institute of Management	278
B-021	企业环境场协同创新过程研究-以港珠澳大桥钢筋混凝土沉管隧道安装为例 COLLABORATIVE INNOVATION PROCESS OF ENTERPRISE ENVIRONMENT FIELD-THE CASE STUDY OF REINFORCED CONCRETE IMMERSSED TUNNEL INSTALLATION OF HONGKONG-ZHUHAI- MACAO BRIDGE	Qianchuan Zhong	Panyapiwat Institute of Management	295
B-022	社会艺术培训顾客感知价值的量表开发与实证研究 SCALE DEVELOPMENT AND EMPIRICAL RESEARCH ON CUSTOMER PERCEPTION VALUE OF SOCIAL ART TRAINING	Ding Wang	Panyapiwat Institute of Management	303
B-023	数字环境下中国品牌国际传播机制研究——以 YouTube 平台上的中国品牌为例 INTERNATIONAL COMMUNICATION MECHANISM OF CHINESE BRANDS IN DIGITAL ENVIRONMENT--TAKE CHINESE BRANDS ON YOUTUBE AS AN EXAMPLE	Hongye Li	Panyapiwat Institute of Management	315
B-024	碳中和背景下大学生结果意识对低碳消费行为的影响 THE IMPACT OF COLLEGE STUDENTS' CONSCIOUSNESS OF RESULTS ON LOW-CARBON CONSUMPTION BEHAVIOR IN THE CONTEXT OF CARBON NEUTRALITY	1. Yu Lu 2. Chen Cai	Baise College	326
B-025	探讨员工自我同情、社会支持对职业倦怠的影响研究：职业压力的调节作用 EMPLOYEE SELF SYMPATHY AND SOCIAL SUPPORT OF EMPLOYEES ON JOB BURNOUT: THE MODERATING ROLE OF OCCUPATIONAL STRESS	Jinfeng Li	Dhurakij Pundit University	333
B-026	文化产业视角下美术馆的转型研究——以成都民营美术馆为例 THE TRANSFORMATION OF ART MUSEUMS FROM THE PERSPECTIVE OF CULTURAL INDUSTRY -- TAKE CHENGDU AS AN EXAMPLE	1. Menghan Wu 2. Zhaoqi Peng	Panyapiwat Institute of Management	346



Code	Title	Name - Surname	Affiliation	Page
B-027	游戏数字发行平台质量对消费者行为意向影响研究——基于用户满足的中介效应分析 THE IMPACT OF GAME DIGITAL DISTRIBUTION PLATFORM QUALITY ON CONSUMER BEHAVIOR INTENTIONS——ANALYSIS OF MEDIATING EFFECT BASED ON USER SATISFACTION	1. Hengde Geng 2. Xuemei Sun	Panyapiwat Institute of Management	353
B-028	员工责任、企业声誉与消费者价值共创意愿的关系研究 THE RELATIONSHIP BETWEEN EMPLOYEE RESPONSIBILITY, CORPORATE REPUTATION, AND CONSUMER VALUE CO-CREATION WILLINGNESS	Zhijun Cai	Panyapiwat Institute of Management	367
B-029	在泰国进行高尔夫旅游的中国消费者与需求的关系 THE RELATIONSHIP BETWEEN CHINESE GOLF TOURISM CONSUMERS AND DEMAND IN THAILAND	1. Jin Wang 2. Pak Thaldumrong	Panyapiwat Institute of Management	377
B-030	知识员工非物质激励对创新绩效的影响研究—以组织认同为中介变量 THE IMPACT OF KNOWLEDGE WORKERS' NON-MATERIAL INCENTIVES ON INNOVATION PERFORMANCE: ORGANIZATIONAL IDENTITY AS A MEDIATING VARIABLE	1. Danni Song 2. Ao Chen	Panyapiwat Institute of Management	390
B-031	中国乡村创业者的职业经历丰富度测度与比较 MEASUREMENT AND COMPARISON OF CAREER EXPERIENCE RICHNESS OF RURAL ENTREPRENEURS IN CHINA	Mingyue Liu	Panyapiwat Institute of Management	401
B-032	自我损耗理论视角下绩效压力对亲组织非伦理行为的作用机制研究 THE INFLUENCE MECHANISM OF PERFORMANCE PRESSURE ON EMPLOYEE UNETHICAL PRO-ORGANIZATIONAL BEHAVIOR FROM THE PERSPECTIVE OF EGO-DEPLETION THEORY	Zhoufan Liu	Panyapiwat Institute of Management	413





### *C-Communications*

Code	Title	Name - Surname	Affiliation	Page
C-001	对外汉语教师跨文化交际研究-以泰国寺庙学校基督教信仰汉语老师为例 CROSS-CULTURAL COMMUNICATION OF CHINESE TEACHERS-TAKE CHINESE TEACHER OF CHRISTIAN FAITH AT THAI TEMPLE SCHOOL AS AN EXAMPLE	1. Shaofan Zhang 2. Yi Shao 3. Pailin Chernpech 4. Min Zheng	1,2 Jinan University 3,4 Dhonburi Rajabhat University	427



*D-Economics*

Code	Title	Name - Surname	Affiliation	Page
D-001	R&D INVESTMENT, INNOVATION EFFICIENCY, VALUE CREATION AND DIGITAL TRANSFORMATION OF LARGE ENTERPRISES IN CHINA— —A MODERATED MEDIATION MODEL	1. Dazhi Yue 2. Shuanping Gao	Xiamen Institute of Technology, China	435
D-002	THE DUNNING’S OLI FRAMEWORK AS A KEY FOR MNE CONSIDER WHERE TO PLACE FDI	Jia Hou	Xiamen Institute of Technology, China	456
D-003	VARIOUS PERSONNEL POLICIES TO PROMOTE DIVERSITY IN EUROPEAN COMPANIES	Kyoko Kato	Shibaura Institute of Technology (SIT)	459
D-004	“保险+期货” 下的广西糖料蔗收入保险研究 GUANGXI SUGAR CANE INCOME INSURANCE UNDER “INSURANCE+FUTURES”	Jianming Jiang	Panyapiwat Institute of Management	465
D-005	企业员工激励问题及对策研究——以麦田房产有限公司为例 THE PROBLEMS AND COUNTERMEASURES OF ENTERPRISE STAFF MOTIVATION——TAKING MAITIAN REAL ESTATE CO., LTD. AS AN EXAMPLE	1. Minghao Li 2. Zhaomei Chi 3. Jian Chu	Panyapiwat Institute of Management	476
D-006	中国政府扶持在农业产业链优化与区域特色农产品竞争力关系中的调节作用研究 THE MODERATION EFFECT OF THE CHINESE GOVERNMENT SUPPORTS IN THE RELATIONSHIP BETWEEN THE OPTIMIZATION OF THE AGRICULTURAL INDUSTRY CHAIN AND THE COMPETITIVENESS OF REGIONAL CHARACTERISTIC AGRICULTURAL PRODUCTS	Fayong Gong	Panyapiwat Institute of Management	491



## E-Education

Code	Title	Name - Surname	Affiliation	Page
E-001	A CORRELATIONAL STUDY OF MILLENNIAL TEACHERS' PERCEPTION TOWARD THE PRINCIPAL'S TRANSFORMATIONAL LEADERSHIP STYLE AND THEIR JOB SATISFACTION AT KANI BASIC EDUCATION HIGH SCHOOL IN SAGAING REGION, MYANMAR	1. Mai Mar Mar Aung 2. Watana Vinitwatanakhun	Graduate School of Human Science, Assumption University	501
E-002	A SURVEY STUDY OF THE OPINIONS AND SATISFACTION OF MATTHAYOMSUKSA VI STUDENTS AT PANYAWORAKUN SCHOOL WITH A NEW VERSION OF VOCABULARY EXERCISES	Thoseporn Sophitthammakun	Foreign Languages Department, Panyaworakun School, SESAO 1	513
E-003	THE RELATIONSHIP BETWEEN TEACHERS' PERCEPTION TOWARDS THE DIVISION HEAD'S TRANSFORMATIONAL LEADERSHIP STYLE AND TEACHERS' MOTIVATION AT PHUKET THAIHUA ASEAN WITTAYA SCHOOL, THAILAND	1. Chang Liu 2. Poonsri Vate-U-Lan	Graduate School of Human Sciences, ASSUMPTION University	526
E-004	THE RELATIONSHIP BETWEEN TEACHERS' PERCEPTIONS TOWARDS THEIR LEADERSHIP CAPACITY AND SCHOOL'S ORGANIZATIONAL CLIMATE AT CHOI HUNG ESTATE CATHOLIC SCHOOL, HONGKONG, CHINA	1. Yanan YU 2. Poonsri Vate-U-Lan	Assumption University	537
E-005	高校非洲留学生对教育服务满意度及提升途径研究 THE STATUS QUO AND IMPROVEMENT FOR THE SATISFACTION WITH EDUCATIONAL SERVICE OF AFRICAN STUDENTS IN CHINA	Lin Zhou	Panyapiwat Institute of Management	547
E-006	浅论对外汉语词汇教学中同义词误用和相应的教学策略 BRIEF DISCUSSION ON THE MISUSE OF SYNONYMS AND CORRESPONDING TEACHING STRATEGIES IN THE VOCABULARY TEACHING OF TEACHING CHINESE AS A FOREIGN LANGUAGE VOCABULARY	1. Xiaoxue He 2. Zhishan Liu	Phranakhon Si Ayutthaya Rajabhat University	557
E-007	“三全育人”视域下三双模式——国际中文教育本科生实习培养实践路径研究 THREE-PAIR MODEL IN THE VIEW OF "THREE COMPLETE EDUCATION"-- PRACTICAL TRAINING PATH OF INTERNATIONAL CHINESE EDUCATION UNDERGRADUATES	1. Jie Shi 2. Zhixuan Wang 3. Yun Xu	1 Chinese Graduate School, Panyapiwat Institute of Management 2,3 Shandong Normal University, International Education College, China	565



Code	Title	Name - Surname	Affiliation	Page
E-008	信息化时代西部民族地区高校教师对信息化教学的适应性研究 ON COLLEGE TEACHERS' ADAPTABILITY TO INFORMATION TEACHING IN ETHNIC AREAS OF WESTERN CHINA IN THE INFORMATION AGE	1. Yuhua Huang 2. Long Ye	Panyapiwat Institute of Management	575
E-009	资源拼凑理论视角下的校企协同创新机制综述研究 UNIVERSITY-INDUSTRY COLLABORATIVE INNOVATION MECHANISM FROM THE PERSPECTIVE OF RESOURCE PATCHWORK THEORY	Qin Ke	Panyapiwat Institute of Management	589



## *F-Engineering and Technology*

Code	Title	Name - Surname	Affiliation	Page
F-001	AERODYNAMIC DRAG REDUCTION OF A GENERIC LORRY MODEL USING CONTINUOUSLY BLOWING JETS	1. Peerapong Kumkhuntod 2. Kamthon Septham	King Mongkut's University of Technology Thonburi	601
F-002	COMPARISON OF THE CLASSIFICATION OF PHONOCARDIOGRAMS WITH BREATHING SOUND NOISE BY MACHINE LEARNING ALGORITHMS	1. Neungreutai Prasert 2. Thanaset Thosdeekoraphat 3. Jessada Tanthanuch	1 School of Biomedical Innovation Engineering, Suranaree University of Technology 2 School of Electronic Engineering, Suranaree University of Technology 3 School of Mathematics, Suranaree University of Technology	612
F-003	COST-EFFECTIVENESS PRODUCTIVITY IMPROVEMENT	1. Paritud Bhandhubanyong 2. Kyoko Kato	1 Panyapiwat Institute of Management 2 Shibaura Institute of Technology	624



### *G-Library Arts*

Code	Title	Name - Surname	Affiliation	Page
G-001	民族地区文化旅游产品层级及体验质量研究--以基诺山寨文化旅游产品为例 CULTURAL AND TOURISM PRODUCT LEVEL AND EXPERIENCE QUALITY IN ETHNIC MINORITY AREAS-- TAKE JINUO SHANZHAI CULTURAL TOURISM PRODUCTS AS AN EXAMPLE	Yi Liu	Panyapiwat Institute of Management	630
G-002	企业文化与创新能力关系研究——以日本企业为例 THE RELATIONSHIP BETWEEN CORPORATE CULTURE AND INNOVATION ABILITY RESEARCH -- TAKE JAPANESE COMPANIES AS AN EXAMPLE	Jianna Huang	Panyapiwat Institute of Management	644
G-003	《新 HSK5000 词分级词典》中的敬辞及敬辞反映的中国文化 HONORIFICS IN THE NEW HSK5000 WORD CLASSIFICATION DICTIONARY AND THE CHINESE CULTURAL CONNOTATION REFLECTED BY HONORIFICS	1. Daqian Li 2. Jinze Liu 3. Tiwaporn Udomwong	1 College of Humanities Chiang Rai Rajabhat University 2 International affair Siam University	658

## *H-Management*

Code	Title	Name - Surname	Affiliation	Page
H-001	A CASE STUDY ON REFLECTION AND ASSIGNMENT OF HTTEA THINK TANK'S LEADERSHIP SIGNATURE: BASE ON THE MIT FOUR CAPABILITIES MODEL	1. Wei Meng 2. Xiaoyin Zhang	1,2 CIBA, Dhurakij Pundit University 1 MIT Sloan School of Management, U.S.A	671
H-002	A SUMMARY OF THE RESEARCH ON CHINA'S CYBERSECURITY RISK IDENTIFICATION AND CONTROL BASED ON NGOS	MengRan Li	Dhurakij Pundit University	685
H-003	ACADEMIC LEADERSHIP PRACTICE FOR COLLEGE OF ART AND DESIGN, GUANGDONG UNIVERSITY OF PETROCHEMICAL TECHNOLOGY	Yilan Li	Guangdong University of Petrochemical Technology	702
H-004	HOW SUSCEPTIBILITY TO EMOTIONAL INFECTION AFFECTS EMPLOYEES' WORK PROCRASTINATION: THE MODERATING EFFECT OF SELF-MONITORING	1. Sen Liu 2. Ching-Chou Chen	Dhurakij Pundit University	714
H-005	PERCEPTION OF COST AFFECTING PERCEPTION OF DESTINATION AND SATISFACTION: ANDAMAN AND GULF COAST MEDICAL TOURISM	1. Darin Rungklin 2. Kanon Trichan 3. Issarut Rinthisong	Faculty of Management Sciences, Prince of Songkla University	731
H-006	THE RELATIONSHIP BETWEEN TEACHERS' PERCEPTION TOWARDS ORGANIZATIONAL CULTURE AND THEIR JOB SATISFACTION AT KANTANA INSTITUTE, THAILAND	1. Zhe Yang 2. Poonsri Vate-U-Lan	Graduate School of Human Sciences, ASSUMPTION University	745
H-007	THEORETICAL ANALYSIS OF THE IMPACT OF STRATEGIC HUMAN RESOURCE MANAGEMENT ON EMPLOYEE PERFORMANCE	1. Chunxing Zhao 2. Chunyan Zhao	Panyapiwat Institute of Management	757
H-008	WHAT GOES AROUND COMES AROUND? HOW LEADERS WITH INCLUSIVE HUMOR PROMOTE CONSTRUCTIVE DEVIANT BEHAVIORS OF EMPLOYEES	1. Shanlan Zhan 2. Ching-Chou Chen	Dhurakij Pundit University	768
H-009	WHY EMPLOYEES HAVE LOW PSYCHOLOGICAL RESILIENCE: THE BOTH EFFECTS OF INTERNET ADDICTION AND WORKPLACE INCIVILITY	1. Yuan Zong 2. Ching-Chou Chen	Dhurakij Pundit University	779
H-010	悖论式领导对企业创新绩效的影响研究 THE INFLUENCE OF PARADOXICAL LEADERSHIP ON ENTERPRISE INNOVATION PERFORMANCE	1. Qiuying Lei 2. Zhijian Xu	Panyapiwat Institute of Management	799
H-011	并购财务风险因素案例分析--以阿里并购拉查达为例 FINANCIAL RISK FACTORS IN M&A -- TAKE ALI'S ACQUISITION OF LAZADA AS AN EXAMPLE	1. Zitong Huo 2. Zhaomei Chi	Panyapiwat Institute of Management	810



Code	Title	Name - Surname	Affiliation	Page
H-012	大数据环境下的客户关系管理创新发展研究 INNOVATIVE DEVELOPMENT OF CUSTOMER RELATIONSHIP MANAGEMENT IN BIG DATA ENVIRONMENT	1. Ziyuan Li 2. Yishu Liu 3. Hanfei Zhu	1,3 Xiamen Institute of Technology, China 2 anyapiwat Institute of Management	824
H-013	管理者自利与企业创新绩效：基于研发投入的中 介效应 MANAGER SELF-INTEREST AND CORPORATE INNOVATION PERFORMANCE: BASED ON THE MEDIATING EFFECT OF R&D INVESTMENT	Shunping Tan	Panyapiwat Institute of Management	829
H-014	顾客参与服务创新的研究综述——基于文献计量 学的分析 CUSTOMER INVOLVEMENT IN SERVICE INNOVATION: BASED ON THE VIEW OF BIBLIOMETRICS	1. Guoli Bian 2. Qing Li	Panyapiwat Institute of Management	845
H-015	价值共创视角下体育非物质文化遗产与旅游资源 融合研究 THE INTEGRATION OF SPORTS INTANGIBLE CULTURAL HERITAGE AND TOURISM RESOURCES FROM THE PERSPECTIVE OF VALUE CO-CREATION	Hongdong Hu	Panyapiwat Institute of Management	862
H-016	价值链嵌入对企业绩效的影响研究——基于文献 计量的视角 THE IMPACT OF VALUE CHAIN EMBEDDING ON FIRM PERFORMANCE—— BASED ON BIBLIOMETRICS ANALYSIS	1. Li Liu 2. Qing Li	Panyapiwat Institute of Management	871
H-017	类亲情交换与高校教师专业发展的直接效应检验 A TEST OF THE DIRECT EFFECT OF FAMILY-LIKE EXCHANGE AND UNIVERSITY TEACHERS' PROFESSIONAL DEVELOPMENT	Li Yi	Panyapiwat Institute of Management	889
H-018	拼多多 APP 用户使用意愿影响因素研究：基于 UTAUT 模型的实证研究 FACTORS INFLUENCING CONSUMER USE INTENTION ON PINDUODUO: AN EMPIRICAL STUDY BASED ON UTAUT MODEL	1. Yanfang Tan 2. Ao Chen	Panyapiwat Institute of Management	902
H-019	企业家精神与员工创新行为的关系研究—基于组 织柔性的调节作用 THE RELATIONSHIP BETWEEN ENTREPRENEURSHIP AND EMPLOYEE INNOVATIVE BEHAVIOR——BASED ON THE REGULATION OF ORGANIZATIONAL FLEXIBILITY	Cheng Pang	Panyapiwat Institute of Management	914
H-020	手术团队操作流程知识转移过程研究——基于知 识基础观与实践基础观整合的视角 THE KNOWLEDGE TRANSFER PROCESS OF SURGICAL TEAM OPERATION PROCESS——BASED ON THE INTEGRATION OF THE KNOWLEDGE-BASED VIEW AND THE PRACTICE-BASED VIEW	1. Digong Zuo 2. Ao Chen	Panyapiwat Institute of Management	923





Code	Title	Name - Surname	Affiliation	Page
H-021	TR 大酒店服务质量评价与改进策略研究 SERVICE QUALITY EVALUATION AND IMPROVEMENT STRATEGY OF TR HOTEL	1. Lin Wu 2. Hongyan Shang 3. Xianqian Yang	1,2 Panyapiwat Institute of Management 3 Tongren Preschool Education College, China	936
H-022	乡村旅游目的地游客感知质量维度构建及实证研究 EMPIRICAL STUDY AND DIMENSION CONSTRUCTION ON TOURIST PERCEPTION QUALITY IN DESTINATION OF RURAL TOURISM	1. Fengping Wen 2. Songbai Liu	1,2 Panyapiwat Institute of Management 1 Institute of Tourism Management Baise University	951
H-023	学生参与大学治理效果的灰色模糊综合评价 GREY FUZZY COMPREHENSIVE EVALUATION ON THE EFFECT OF STUDENTS PARTICIPATION IN UNIVERSITY GOVERNANCE	Xing Hong	Panyapiwat Institute of Management	964
H-024	虚荣心对职业决策自我效能感的影响 THE INFLUENCE OF VANITY ON CAREER DECISION-MAKING SELF-EFFICACY	Chao Li	Dhurakij Pundit University	974
H-025	中层管理人员个人知识心理所有权对知识共享的影响：感知信任的调节作用 THE IMPACT OF MIDDLE MANAGERS KNOWLEDGE-BASED PSYCHOLOGICAL OWNERSHIP ON KNOWLEDGE SHARING: THE MODERATING ROLE OF PERCEIVED TRUST	Chen Cai	<ul style="list-style-type: none"> <li>• Panyapiwat Institute of Management</li> <li>• Baise College, China</li> </ul>	986



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*Engineering and Technology*



# COMPARISON OF THE CLASSIFICATION OF PHONOCARDIOGRAMS WITH BREATHING SOUND NOISE BY MACHINE LEARNING ALGORITHMS

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## Abstract

This research aims to classify between normal heart sounds and abnormal heart sounds (heart murmurs and clicks) by machine learning techniques. This study made the assumption that the obtained heart sound may be interfered with by the breath sound noise. The test files were manipulated by overlaying the breathing sound noise on the phonocardiograms of heart sounds. The data of breathing sound noise and heart sound was obtained from Respiratory Auscultation (<https://www.mediscuss.org/respiratory-auscultation/>) and Heart Sound & Murmur Library, University of Michigan, respectively. Moreover, the files of heart sounds were processed by changing tempos to be faster from 0%, 10%, 20%, 30%, 40%, and 50%, which were done by Audacity software. The different tempos of each heart sound file represent the different heartbeat rates of the same person. In this work, five techniques of machine learning algorithm, which were Random Forest, Neural Network, Deep Learning, Support Vector Machine, Naïve Bayes, were applied for making the model of classification. The methods used for model validation were split validation and cross-validation. The data for classification were the images of the waveform of processed noisy heart sounds and spectrogram of the processed sound. Software used for the working of classification was RapidMiner studio. It was found that the Random Forest technique with cross-validation of a spectrogram of sound files provided the best performance, which had accuracy = 93.69%, precision = 97.41%, recall = 89.68%, and F1-score = 93.39%.

**Keywords:** Phonocardiogram Spectrogram Classification Spectrogram Machine Learning

## Introduction

According to the World Health Organization, cardiovascular diseases (CVDs) are one of the main causes of death globally. An estimated 17.9 million people died from CVDs in 2019 representing 32% of all global deaths. Out of the 17 million premature deaths (under the age of 70) due to noncommunicable diseases in 2019, 38% were caused by CVDs. It is important to detect cardiovascular disease as early as possible so that management with counseling and medicines can begin (WHO, 2021). Auscultation by using a stethoscope for listening to the heart sound is a part of physical examination. The stethoscope is a basic medical device that doctors always use to listen to mechanical valvular activity. It is a valuable method for CVDs detection. These diseases could be identified easily with the variations in the sound produced due to heart activity. That is the most primary diagnosis method for the initial detection of heart valves which is also an economical and simple screening test.

Heart sounds are created by blood flow and vibrations of tissues during the cardiac cycle. Under normal conditions, blood flow is laminar and silent. With structural or hemodynamic changes



turbulent flow results, which causes vibrational waves. These waves are transmitted through the chest wall that is translated into sounds known as heart sounds or Phonocardiogram "PCG". PCG signal analysis is a common method for evaluating the condition of the heart and detecting possible anomalies.

Artificial intelligence (AI) is a science that gathers knowledge in many disciplines. In particular, it is the combination of science and engineering to develop machines or computer systems to be intelligent, able to think, calculate, analyze, learn and make decisions as rational as the human brain, and be able to learn, develop and improve its work processes to increase the potential of artificial intelligence itself (Sittichanbuncha, 2021). AI has been developed since the 1950s to the present day and can be used in a variety of areas, including the medical fields and healthcare industry such as diagnosing diseases detecting lung cancer, classifying skin lesions in skin images assessing the risk of sudden cardiac death or other heart diseases based on electrocardiograms, cardiac MRI images, and including phonocardiogram (Schmitt, 2020). Currently, Artificial intelligence (AI) algorithms are widely used in the classification of heart sound abnormalities due to the analysis of heart sound signals playing an irreplaceable role in the early diagnosis of heart disease and containing a large amount of pathological information about each part of the human heart. Heart sounds can be detected and recorded by Phonocardiogram (PCG) (Yang et al., 2019). As a non-invasive method to detect and diagnose heart disease, PCG signals have been paid more and more attention by researchers.

### **Research Objectives**

1. To classification normal heart sound and abnormal heart sound from obtained phonocardiogram with breathing sound noise files by machine learning algorithms.
2. To compare the performance of 5 machine learning algorithms in the classification.

### **Literature Review**

Aktar, and Andrei (2020) proposed a heartbeat audio classifier software design that could differentiate normal heartbeats and heart murmurs by Convolutional Neural Network (CNN) algorithm. The software could also differentiate the types of heart sounds. The CNN achieved an accuracy of approximately 79% on unseen test data, with an AUROC score of 0.78.

Baydoun, Safatly, Ghaziri, and El Hajj (2020) proposed an approach to combine multiple classification models of heart sounds to improve accuracy. The classification system by combining the LogitBoost model and the Bagging model provided the best score of 86.6% of accuracy, with a sensitivity and specificity of more than 90%, and 83% respectively.

Bourouhou, Jilbab, Nacir, and Hammouch (2020) proposed a classification algorithm based on the extraction of 20 features from segmented phonocardiogram (PCG) by applying four types of machine learning classifiers, which were k-nearest neighbor (KNN), support vector machines (SVM), Tree Classifier, and Naïve Bayes. The results showed that Naive Bayes had the best classification performance.

Zhang, Han, and Deng (2019) proposed the method for heart sound detection using the temporal quasi-periodic features of the heart sound signals. The analysis was done by AMDF of the heart sound spectrogram and the short-term and long-term dependency relation within the temporal quasi-periodic features extracted by long short-term memory (LSTM). This method could effectively detect abnormal heart sound.

Chowdhury, Khandakar, Alzoubi, Mansoor, Tahir, Reaz, and Al-Emadi (2019) proposed the prototype model of a smart digital-stethoscope system to monitor a patient's heart sounds. It helped in



diagnosis any abnormality in a real-time manner. The model was designed by modifying an analog stethoscope. The stethoscope was added up by a miniaturized microcontroller with built-in Bluetooth low energy for digitization and transmission. The obtained data were classified by machine learning algorithms, which were Decision tree, discriminant analysis, support vector machines (SVM), k-nearest neighbor (KNN), and ensembles classifiers. The results showed that the Ensemble algorithm could outperform all the trained competition algorithms with an overall accuracy of 86.02%.

Yang, Li, Zhang, and Yang (2020) proposed the novel envelope extraction model which could use to estimate the cardiac cycle of each PCG signal. They combined the empirical mode decomposition (EMD) technique and the proposed envelope model to extract the time-domain features. The feature vectors were extracted from both the frequency-domain features and wavelet-domain features. By using the support vector machine (SVM) classifier to detect the normal and abnormal PCG signals, the model had an accuracy of more than 96%.

## **Methodology**

### ***1. The heart sound files***

The PCG of heart sound files were obtained from Heart Sound & Murmur Library, University of Michigan. They were MP3-type with a 128kbps bit rate. There were 2 files of normal heart sounds and 21 files of abnormal heart sound including murmurs and clicks sounds.

### ***2. Breathing sound noise preparation***

The breathing sound noise was obtained from Respiratory Auscultation (<https://www.mediscuss.org/respiratory-auscultation/>). The file was also MP3 type with a 192kpbs bit rate. The sound was extended by repeating the sound to be longer closed to the time duration of heart sound by Audacity software.

### ***3. Overlaying breathing sound noise over heart sound***

In this step, we overlaid the extended breathing sound and heart sound files together by the Audacity software.

### ***4. Changing tempo***

We considered that the different activities of each person change the speed of breathing rate and heart rate. To simulate the situation, we made up the data by changing the tempos of the noisy heart sounds by Audacity software. The sound files were changed by setting the tempo to be faster from 0%, 10%, 20%, 30%, 40%, and 50%, and then exported to WAV files format. This technique still preserved the frequency of the wave.

### ***5. Conversion to PNG spectrogram***

Even the classification software, RapidMiner studio, had no audio library for classification, but it has many powerful functions for image processing. In this step, we wanted to make a comparison of using waveform files and spectrogram of sound as data sources for the machine learning part. Audacity software could display spectrogram in the Mel-frequency scale of each WAV file. The PNG files of the spectrogram were exported for classification.

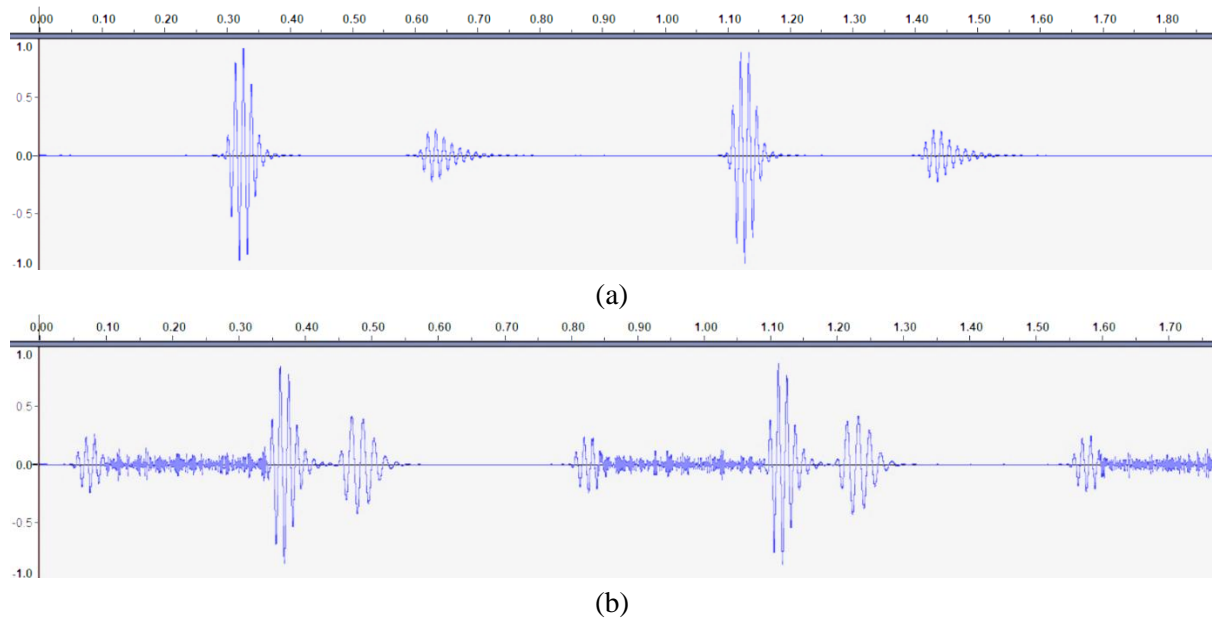
## 6. Setting the machine learning system for classification between normal heart sound and abnormal heart sound

In the last step, we set RapidMiner studio software to classify normal and abnormal heart sound. We used split validation and cross-validation for data manipulation. Here, 5 techniques of machine learning algorithm, which were Random Forest, Neural Net, Deep Learning, Support Vector Machine, Naïve Bayes, were applied for making the model of classification. The proposed 5 methods are very well-known machine learning techniques using in the classification. For the model obtained, we considered the confusion matrices and calculated accuracy, precision, recall, and F1-score.

### Results

#### 1. The heart sound files

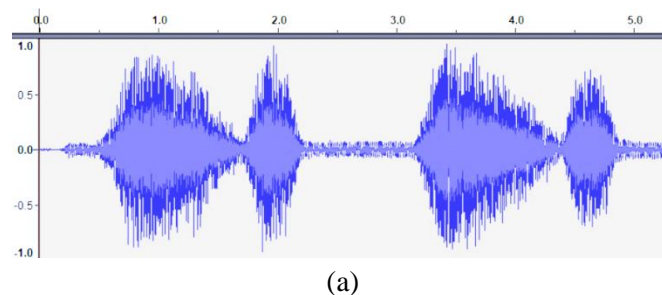
We provided examples of the time waveform of a PCG cardiac cycle in figure 1.

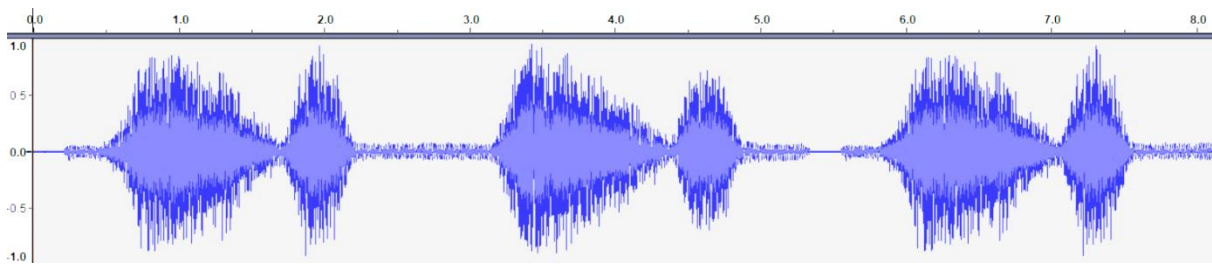


**Figure 1:** The time waveform of a PCG cardiac cycle in (a) normal and (b) abnormal

#### 2. Breathing sound noise preparation

By the original breathing sound (figure 2 (a)), we extended the sound noise by repeating the sound (figure 2 (b)).



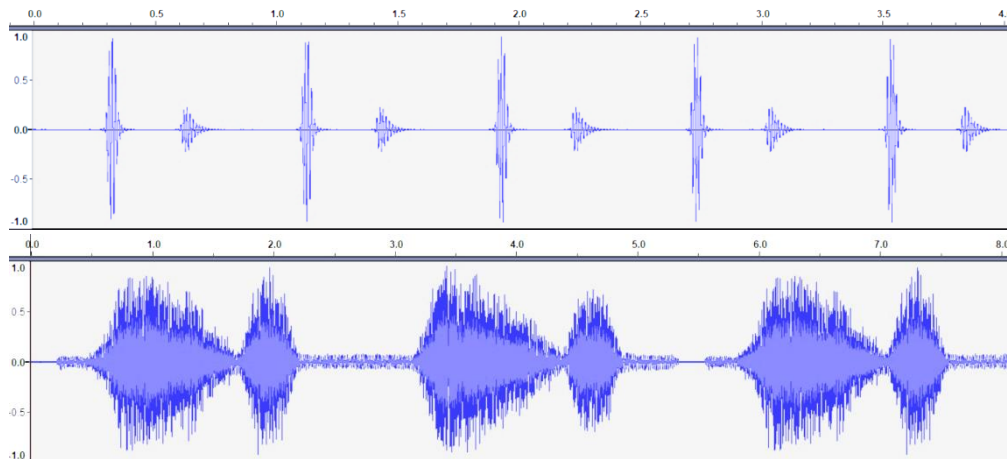


(b)

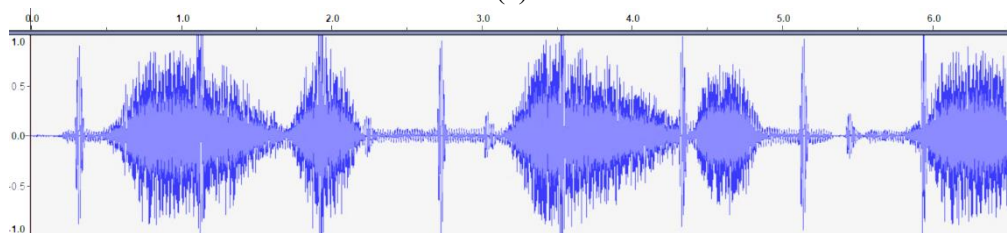
**Figure 2:** (a) Original breathing sound noise, and (b) extended sound noise

### 3. *Overlaying breathing sound noise over heart sound*

The PCG sound and extended breathing sound (figure 3 (a)) were combined by overlaying (figure 3 (b))



(a)



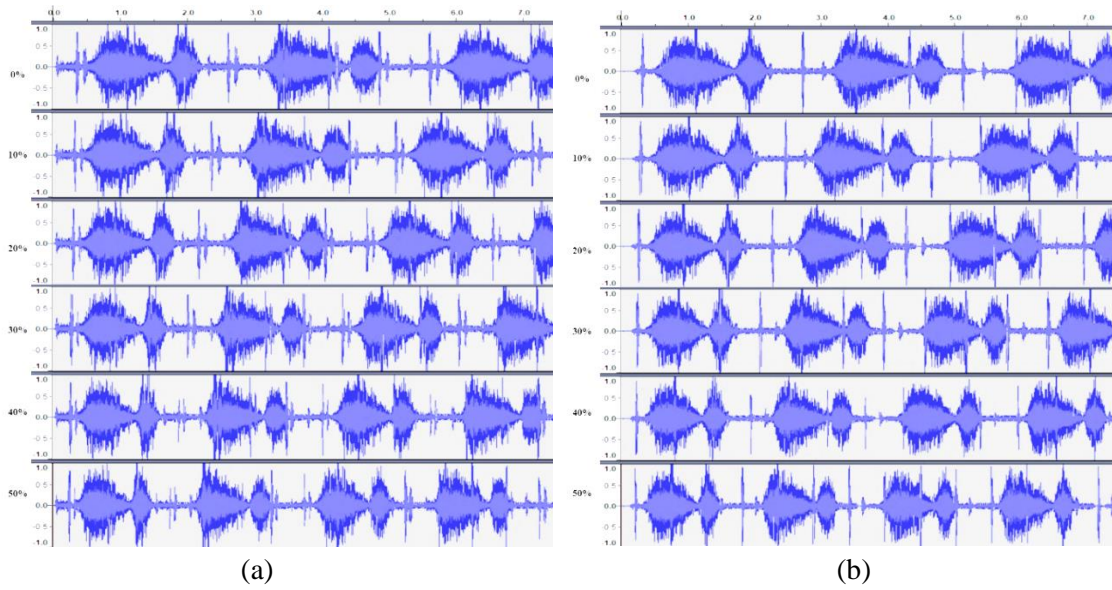
(b)

**Figure 3:** Combining PCG sound and extended breathing sound (a) and results (b)



#### 4. Changing tempo

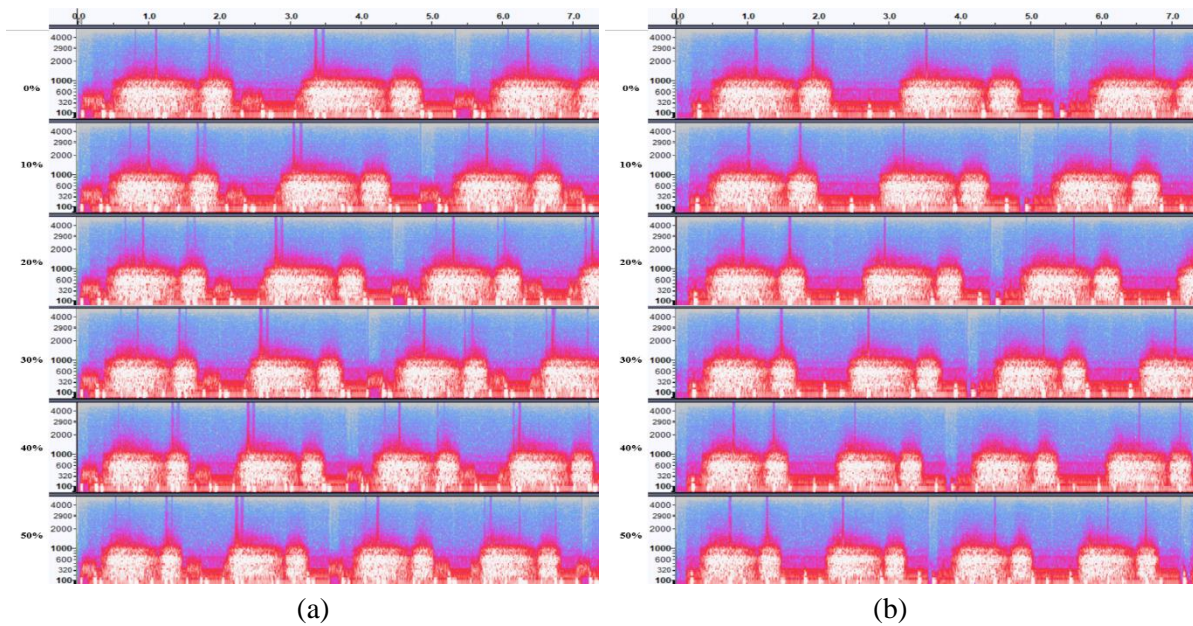
The results of changing tempos were presented in figure 4.



**Figure 4:** Examples of PCG sound modified by changing tempos  
(a) normal heart sound (b) abnormal heart sound

#### 5. Conversion to PNG spectrogram (spectrogram in Mel-frequency scale)

By Audacity software, spectrogram in Mel-frequency scale of each WAV was created and exported as PNG files.



**Figure 5:** Examples of a spectrogram of noisy PCG heart sound  
(a) normal heart sound (b) abnormal heart sound



## 6. Setting the machine learning system for classification between normal heart sound and abnormal heart sound

RapidMiner Studio is a software that can do coding a program by block diagrams. For setting the machine learning system, we did programming as the following steps.

### 6.1 Prepare Datasets

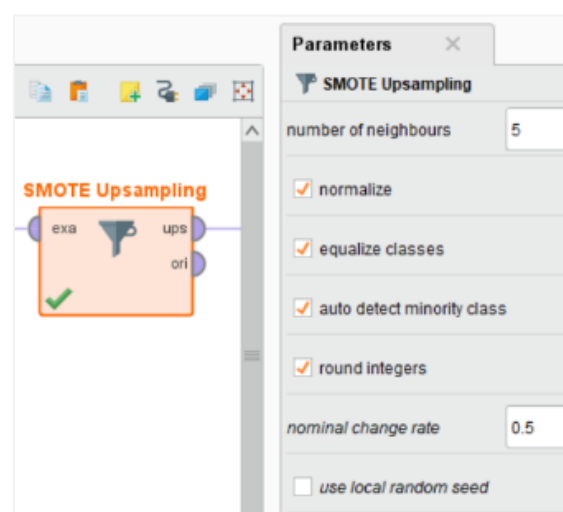
The waveform and spectrogram images were separated into 2 groups, normal and abnormal. The data would be used for training and testing the models. The block diagram code and the setting were shown in figure 6. The data used as input data were waveform images and spectrogram images.



**Figure 6:** Block diagram for datasets preparation

### 6.2 SMOTE Up-sampling

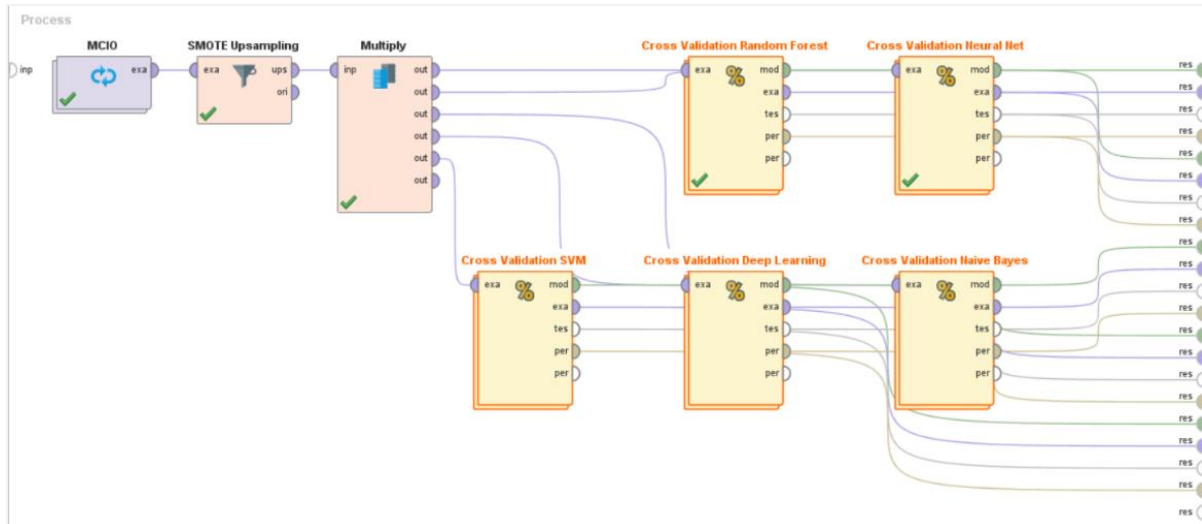
Since the ratio of a number of normal heart sound data (12 files) and abnormal heart sound data (126 files) were quite different. For reducing the unbalance data problem, we applied Synthetic Minority Over-sampling Technique or SMOTE to up-sampling the number of normal heart sound data.



**Figure 7:** Block diagram for SMOTE up-sampling setting

### 6.3 Process

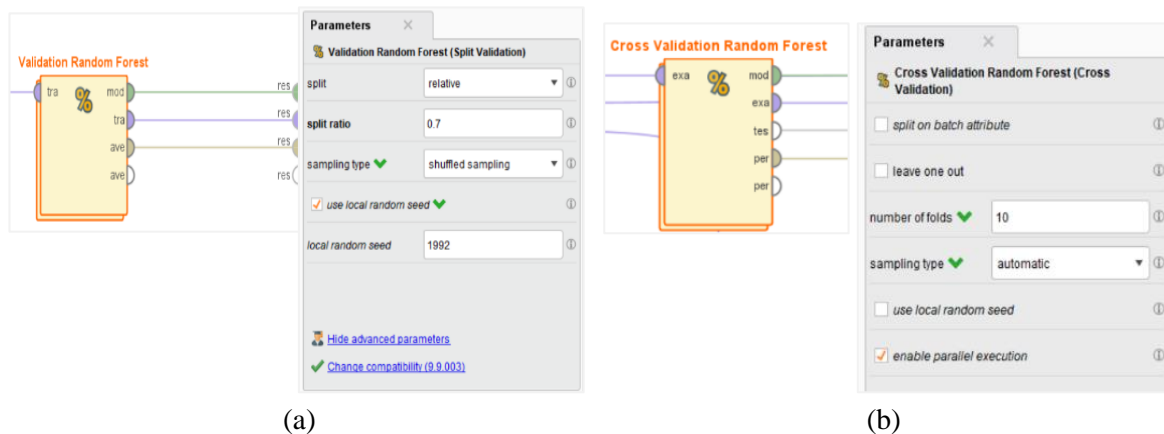
We used the “Multiply” operator for creating copies of our data. The Multiply operator helped us in making many machine learning techniques models according to our suggested algorithms parallelly. Here, the multiply” operator was connected to Random Forest, Neural Network (NN), Deep Learning, Support Vector Machine (SVM), Naïve Bayes block diagrams.



**Figure 8:** Block diagram for setting models parallelly by the Multiply operation

### 6.4 Validation setting

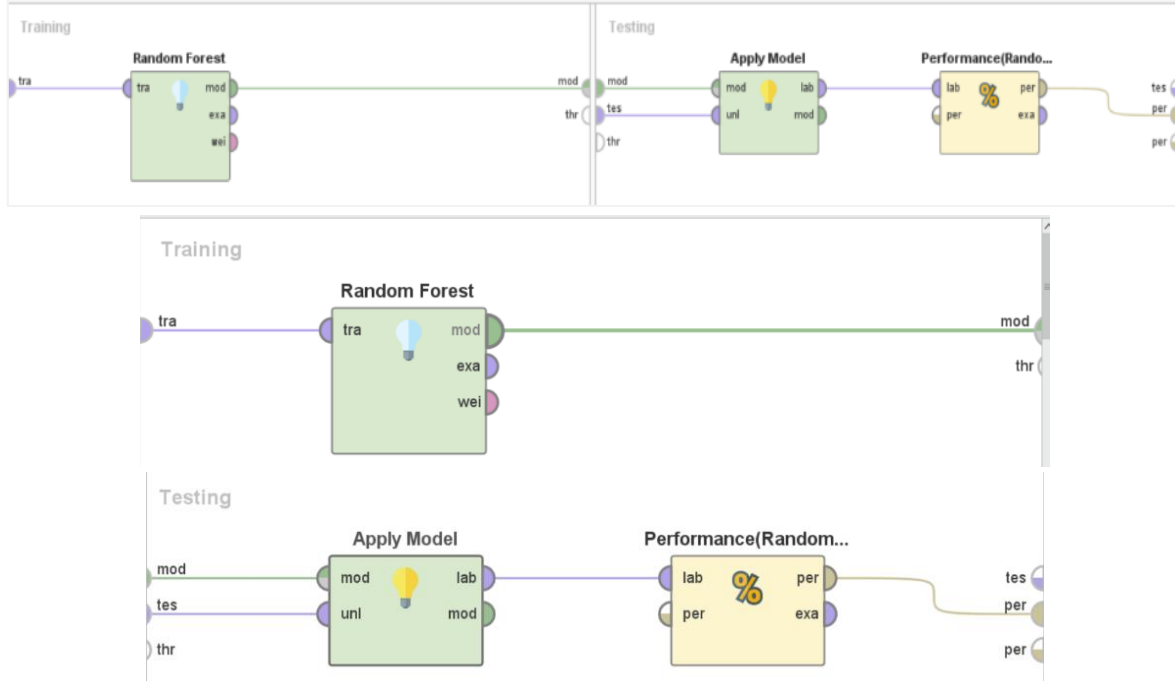
In this step, we used the data for making models and tested models obtained, called validation. The methods used for validation were split validation and cross-validation. For the split validation, 3 cases for ratios of training sets to testing sets were considered, 70%:30%, 75%:25%, and 80%:20%. All four methods were considered for performance evaluation.



**Figure 9:** Block diagram for setting parameters for validation  
 (a) split validation (b) cross-validation

### 6.5 Making models

In this part, all models of 5 algorithms with 4 methods of validation were created and evaluated the performance.



**Figure 10:** Example of a Block Diagram for Model Creating and Model Evaluation

## 7. Performance Evaluation

### 7.1 Results by using waveform files

**Table 1:** 70% Training and 30% Testing Split Validation

Method	Accuracy	Recall	Precision	F1-score
Random Forest	82.89%	77.50%	88.57%	82.67%
Neural Net	80.26%	62.50%	100.00%	76.92%
Deep Learning	82.89%	80.00%	86.49%	83.12%
Support Vector Machine	76.32%	65.00%	86.67%	74.29%
Naïve Bayes	78.00%	56.00%	100.00%	71.79%

**Table 2:** 75% Training and 25% Testing Split Validation

Method	Accuracy	Recall	Precision	F1-score
Random Forest	82.54%	78.79%	86.67%	82.54%
Neural Net	87.30%	78.79%	96.30%	86.67%
Deep Learning	80.95%	63.64%	100.00%	77.79%
Support Vector Machine	79.37%	69.70%	88.46%	77.97%
Naïve Bayes	78.00%	56.00%	100.00%	71.79%



**Table 3:** 80% Training and 20% Testing Split Validation

Method	Accuracy	Recall	Precision	F1-score
Random Forest	80.00%	84.00%	77.78%	80.77%
Neural Net	86.00%	72.00%	100.00%	83.72%
Deep Learning	88.00%	80.00%	95.24%	86.96%
Support Vector Machine	76.00%	72.00%	78.26%	75.00%
Naïve Bayes	78.00%	56.00%	100.00%	71.79%

**Table 4:** Cross-Validation

Method	Accuracy	Recall	Precision	F1-score
Random Forest*	86.20%	82.54%	88.89%	85.60%
Neural Net	83.74%	75.40%	90.48%	82.25%
Deep Learning	83.37%	76.98%	88.18%	82.20%
Support Vector Machine	77.37%	70.63%	81.65%	75.74%
Naïve Bayes	71.78%	46.03%	95.08%	62.03%

7.2 Results by using spectrogram of sound files

**Table 5:** 70% Training and 30% Testing Split Validation

Method	Accuracy	Recall	Precision	F1-score
Random Forest	92.11%	90.00%	91.74%	90.86%
Neural Net	81.58%	85.00%	80.95%	82.93%
Deep Learning	80.26%	75.00%	85.71%	80.00%
Support Vector Machine	75.00%	52.50%	100.00%	68.85%
Naïve Bayes	70.00%	44.00%	91.67%	59.46%

**Table 6:** 75% Training and 25% Testing Split Validation

Method	Accuracy	Recall	Precision	F1-score
Random Forest	92.06%	90.91%	93.75%	92.31%
Neural Net	74.60%	66.67%	81.48%	73.33%
Deep Learning	80.95%	48.48%	80.00%	60.37%
Support Vector Machine	73.02%	44.00%	100.00%	61.11%
Naïve Bayes	70.00%	44.00%	91.67%	59.46%

**Table 7:** 80% Training and 20% Testing Split Validation

Method	Accuracy	Recall	Precision	F1-score
Random Forest	92.00%	88.00%	95.65%	91.67%
Neural Net	88.00%	80.00%	95.24%	86.96%
Deep Learning	82.00%	84.00%	80.77%	82.35%
Support Vector Machine	74.00%	48.00%	100.00%	64.86%
Naïve Bayes	70.00%	44.00%	91.67%	59.46%

**Table 8:** Cross Validation

Method	Accuracy	Recall	Precision	F1-score
Random Forest*	93.69%*	89.68%*	97.41%*	93.39%*
Neural Net	86.89%	76.98%	96.04%	85.46%
Deep Learning	87.31%	83.33%	90.52%	86.78%
Support Vector Machine	75.78%	51.59%	100.00%	68.07%
Naïve Bayes	69.46%	48.41%	83.56%	61.30%

**Remark** \*The model which had the highest performance.

## Discussion

By the results proposed, we found that the Random Forest algorithm was the best one for sound classification. It provided the highest accuracy in almost all validations. For the validation of the model, the cross-validation technique always performed better than split validation. Random Forest algorithm also worked better in the classification of spectrogram compared to the classification of spectrogram waveform directly, which had accuracy, precision, and F1-score more than 90%.

## Conclusion

It was found that the Random Forest technique with cross-validation of a spectrogram of sound files provided the best performance, which had accuracy = 93.69%, precision = 97.41%, recall = 89.68%, and F1-score = 93.39%.

## Acknowledgment

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