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SMART MEDICAL WASTE CLASSIFICATION, SANITATION AND SEGREGATION KIOSK USING DEEP CONVOLUTIONAL NEURAL NETWORKS FOR HOSPITALS

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Abstract:

The developers, developed Medical Waste Sanitation and Segregation Kiosk Using DCNN for Hospitals to help medical employees in segregating and classifying medical waste using an image processing and to help improve the classifying and segregating system medical facilities use. This system enables an automatic classifying of medical items using a DCNN based algorithm, YOLOv5 and with the use of Arduino Mega Board is also enable an automatic segregating system in order to properly separate medical waste and put in the proper trash bin. The developed system has also an added feature that monitors the level of the trash bin that gives an SMS alert when the bin is full. The system has the potential to help improve the current system in classifying, segregating and sanitizing medical waste with further innovations in the developed system. Based on the results from the system evaluation performed measuring the developed system showed that it can help lessen the risk of contamination from medical waste with the implementation of sanitizing mechanism such as Ultra-violet light. With further improvement of the system, other sanitizing method scan be added to be suitable in other medical wastes. Results based on the data gathered from system evaluation revealed that using a convey or system currently is the optimal design that can make the system work smoothly. And the conveyor can be adjusted in order to be suitable to different sizes of trash bins. Findings from the gathered data also revealed that with the use of DCNN based algorithm suchYOLOv5,the developers achieved an 84.2% accuracy

in the classification of medical waste. In the reliability of the design, the developed system achieved an 88.3% and in the, in the effectiveness of the system, the achieved percentage is 85.5% with respect to the overall function and accuracy of the image processing program.

Keywords **—Computer Engineering, Health Care Waste, Waste Segregation, Environmental Protection.**

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I. INTRODUCTION

Working in the healthcare industry is one of the riskiest jobs available. Professionals throughout this field are continuously exposed to all kinds ofpossible risks in the course of their work. Potential dangers include natural biological infection to bacteria living organisms like infectious diseases and the human immunodeficiency virus (HIV), along with chemical contaminants tofumaric acid and methane dioxide from medical waste produced in hospitals, laboratories, as well as other healthcare centers. Medical waste management is so important in the operation of any medical facility that healthcare centers adhere strictly to the standards and laws of countries all over the world regarding the segregation, treatment, and disposal of these wastes. However, the risk of contaminationorinfectiontomedicalworkers,hospitalemployees,andpatients continues to remain because of the amount of waste produced by healthcare activities, of which approximately 85 percent is considered hazardous material that may be infectious, chemical, or radioactive. Health-careactivitiescanincreasewaste,whichcanhurt one'shealth.The majority of this waste is not any more hazardous than regular household waste. Some types of healthcare waste, on the other hand, pose a greater health risk. Medical waste (15–25 percent of total health-care waste), sharps waste (1 percent), body part waste (1 percent), chemical or pharmaceuti0063al waste (3 percent), and radioactive and cytotoxic waste or broken thermometers (1 percent) less than 1 percent. In the Philippines, Various laws and regulations apply to how hospitals shouldcontrolwastegeneration.Apartfromtheg eneralregulationsthatapplyto allorganizations,hospitalsaresubjecttotherules andregulationsoftheRevised Medical Waste Management Manual (RHCWWM) issued by the Department of Healthin2005.Itcontainsdetailedrulesandproc eduresforclassifyinghospital waste and how to treat, transport, neutralize, and dispose of it. The purpose and aim of this study were to develop a kiosk system that segregates based on the classification of medical waste, sanitizes, and monitor thetrashbinlevelofmedicalwastebinswhichhel pedhealthcareworkerslessen the exposure and infection from hospital wastes. The system used an image processing program for an automatic segregation which, the proponents collected datasets of classification of medical wastes. The system also has sensors that served to indicate the level of the trash bin. Finally, the researchers were eager to contribute in the community hospital to help the healthcare workers lessen their risk in disposing medical waste.

II. METHODOLOGY

The researchers utilized descriptive development research strategy. This kind of research allowed the developers create in a systematic procedure that lessens the burden in creating the developed system. Development research, as opposed to simple instructional development, had been the systematic study of designing, developing, and evaluating instructional programs, processes, and product that must meet criteria of internal consistency and

effectiveness. The researchers created a design of the proposed system that is in-line with the researchers' knowledge on the hardware and software requirements for the development of Medical Waste Classification, Sanitation and SegregationKioskUsingDCNNforHospitals.Th einitialdesignwasthebasisof the development of the system and was subjected to improvements and changes upondevelopmentofthesystem,theresearchersch osethebestfeasibledesign for the prototype development. Asystemevaluationwasconducted by the researchers thru a post-test interview and survey with the respondentsfromtheBarangayHealthClinicofBr gy.Labas,CityofSta.Rosaand/or Computer Engineering experts available for evaluating the proposed system. The feedback from the respondents served as a guide for the improvements in the prototype and in the overall system. Any additional suggestions from the respondents were considered by the researchers for furthering the success of the developed system. The prototype development was after the improvements and iterations in the prototype is implemented and the respondents find thesystemtobesatisfactoryandefficientfromthep ost-testsurveyandinterview. Theengineerproductwasthefinalversionofthepro totypeandwassubjected for the final system evaluation.

III. RESULTS AND DISCUSSIONS

Thedevelopersusedthesystemandsoft warequalitymodelsmadebythe International Organization for Standardization (ISO) and International Electro technical Commission (IEC) recognized as the ISO/IEC 25010.

Assigned Point	Numerical Range	Categorical Response	Verbal Interpretation
4	3.51–4.00	StronglyAgree	Strongly Acceptable
3	2.51–3.50	Agree	Acceptable
2	1.51–2.50	Disagree	Unacceptable
1	1.00–1.50	StronglyDisagree	Strongly Unacceptable

Note:thetableabove showsthe4-pointLikerscaleanditsinterpretation.

Table 1. Summary Evaluation of System Quality in Developing the System for the improvement of classifying and segregating medical wastes.

General Characteristic	Indicator	Weight Mean	Interpretation
Functional Suitability	The use of image processing program helps to make the process of classifying and segregating medical wastes	3.73	**Strongly Acceptable**
Usability	Thesystem'suse ofDCNNmakest hesystemeasyto be used as it makes the functionsautoma tic.	3.51	**Strongly Acceptable**
Performance Efficiency	The system's use of a conveyorsystem makesthe system run smoothly.	3.53	**Strongly Acceptable**
Compatibility	The system's datasetand program can be updated from time to time to train theAIothermedi calwasteitems.	3.0	**Acceptable**

Thetableaboveisthesummaryevaluati onofthedevelopedsystemandthe sub-characteristics of the significant test, which clarifies the dependability percentageyieldsandoverallstability.Table8a boverepresentstheresultofthe performance of the developed system, identified by the classification such as functionality in the statement. The use image processing program is suitable in helping to improve the current system in classifying and segregating medical wastes in medical facilities, that's why it received a weighted mean of 3.73. The system'susabilityandefficiencyreceivedawe ightedmeanof3.51and3.53a strongly acceptable interpretation in using image processing in the system, the developers chose to use a conveyor mechanism for the

overall system to run smoothly.Tomaintainthesystem,thesystem'sdatasetshouldbeupdatedfor theadditionalmedical wasteitemsthatcanbetrainedfortheAI. Thedesignfor thesystemischosentomaketheprototypeastandalonemachinethatcanbe used by the medical personnel.

The result from the summary of evaluation from the developer's test of the system showed that the developed system is capable of helping to improve the currentsystemusedinclassifyingandsegregatingmedicalwastes.

Table 2. Summary Evaluation of the System Quality in Developing the System in Using Germicidal/UV-C Light in sanitizing medical wastes.

General Characteristic	Indicator	Weight Mean	Interpretation
Functional Suitability	Theuseofultraviolet lightis suitableforthedeveloper's designoftheprototype.	3.73	**Strongly Acceptable**
Usability	The ultraviolet light does not require a connection in the microcontroller to function.	3.48	**Acceptable**
Performance Efficiency	The developers were unable to measure the amount disinfection by the ultraviolet light, due to lack of tools for measurement.	3.46	**Acceptable**
Compatibility	The ultraviolet light can be replaced when the unit is defective or damaged. It is availableinstoresandin online shops.	2.85	**Acceptable**

The table above is the summary evaluation of the developed system and the sub-characteristics of the significant test, which clarifies the dependability percentageyieldsandoverallstability.Table9 aboverepresentstheresultofthe performance of the developed system, identified by the classification such as functionalityinthestatement.Theultravioletlightisasuitablesanitizingmethod withrespecttothedeveloper'sdesignofthesystem.withothermethodssuchas misting and spraying sanitizing liquids is not suitable at this time because the moisture can damage the wirings and the circuit boards installed in the prototype. The ultraviolet light received an acceptable interpretation in all categories.

The result from the summary of evaluation from the developer's test of the system showed that the ultraviolet light is capable in sanitizing medical waste materials.

Table 3. Summary Evaluation of the System Quality in Measuring the impact of the developed system in the current system used.

General Characteristic	Indicator	Weight Mean	Interpretation
Functional Suitability	With the use of DCNN in the developed system, the currentsystemcanbe improved.	3.63	**Strongly Acceptable**
Usability	The developed system canbe used in the medical facilities in helping with the segregation of medical waste, with image processing,theclassifying and sanitizing of medical waste materials can be automaticallyputintothe trashbin.	3.57	**Strongly Acceptable**
Performance Efficiency	The image processing in the developed system is helpful in segregating medicalwaste materials in medical facilities.	3.71	**Strongly Acceptable**
Compatibility	The developed system's components can be replaced if defective or damaged. The system's	3.52	**Strongly Acceptable**

The table above is the summary evaluation of the developed system and the sub-characteristics of the significant test, which clarifies the dependability percentageyieldsandoverallstability.Table10 aboverepresentstheresultofthe performance of the developed system, identified by the classification such as functionalityin the statement. The developedsystem can beused in themedical facilities to classify and segregate waste automatically, not like the manual system.Thedevelopedsystemcanhelplessent heriskincontaminationinpeople and in the environment with the use of UV light as a sanitizing method. The overall impact of the developed system received an acceptable interpretation in all categories.

The result from the summary of evaluation from the developer's test of the system showed that the developed system has the capability to help the current system to improve the current manual system in segregating and sanitizingmedical waste materials.

Table 4. Summary Evaluation of the System Quality in Measuring the level of accuracy in medical waste classification and segregation of the proposed system.

General Characteristic	Indicator	Weight Mean	Interpretation
Functional Suitability	theuseofimageprocessingissuitableinthedeveloped system.	3.74	**Strongly Acceptable**
Usability	Thedevelopedsystemobtained a level of accuracy of 84.2% in average	3.54	**Strongly Acceptable**
Performance Efficiency	The developed system can classifymedicalwastewith 84.2% in accuracy. The trained data helps toincreasethelevel of accuracy	3.64	**Strongly Acceptable**
Compatibility	The trained dataset in the developed system are 1050 imagesforthethremedical items; nitrile gloves, blue surgical facemask and 5cc syringe. The use of YOLO v5 is suitable in creating an accurate image processing program	3.51	**Strongly Acceptable**

The table above is the summary evaluation of the developed system and the sub-characteristics of the significant test, which clarifies the dependability percentageyieldsandoverallstability.Table11 aboverepresentstheresultofthe performance of the developed system, identified by the classification such as functionalityin the statement. The developedsystemcan beused in themedical facilities to classify and segregate waste automatically, not like the manual system.Thedevelopedsystemcanhelplessent heriskincontaminationinpeople and in the environment with the use of UV light as a sanitizing method. The overall impact of the developed system received a strongly acceptable interpretation in all categories.

Theresultfromthesummaryofevaluationfromthedeveloper'stestofthe systemshowedthattheMedicalWasteClassification,SanitationandSegregation Kiosk Using DCNN for Hospitals has attained an average accuracy of 84.2%.

Table 5. Summary Evaluation of the System Quality in Measuring the level of Acceptability, Effectiveness and Reliability of Medical Waste Classification, Sanitation and segregation Kiosk Using DCNN for Hospitals

General Characteristics	Sub-Characteristics	Weighted Mean	Average	Interpretation
Portability	Adaptability	3.6	3.60	**Strongly Acceptable**
	Installability	3.7		
	Replaceability	3.5		
Maintainability	Modularity	3.8	3.58	**Strongly Acceptable**
	Reusability	3.4		
	Analyzability	3.9		
	Modifiability	3.8		
	Testability	3.0		
Security	Confidentiality	3.9	3.82	**Strongly Acceptable**
	Integrity	3.9		
	Non-Repudiation	3.9		
	Accountability	3.8		
	Authenticity	3.6		
Reliability	Maturity	3.9	3.60	**Strongly Acceptable**
	Availability	3.7		
	FaultTolerance	3.1		
	Recoverability	3.7		
Functional Suitability	Functional Completeness	3.8	3.80	**Strongly Acceptable**
	Functional Correctness	3.9		
	Functional Appropriateness	3.7		
Performance Efficiency	TimeBehavior	3.8	3.36	**Acceptable**
	Resource Utilization	3.2		
	Capacity	3.1		
Compatibility	Co-existence	3.1	3.1	**Acceptable**
Usability	Appropriateness Recognizability	3.7	3.63	**Strongly Acceptable**
	Learnability	3.6		
	Operability	3.8		
	User Error Protection	3.6		
	User Interface Aesthetics	3.2		
	Accessibility	3.9		
CompositeMean			3.56	**Strongly Acceptable**

The table above is the summary evaluation of the level of acceptability, effectiveness and reliability of the developed system and the sub-characteristics of the significant test, which clarifies the dependability percentage yields and overall stability. Table 12 above represents the result of the performance of the developed system, identified by the classification such as functionality in the statement. The developed system is evaluated by the IT and Computer Engineering professionals and obtained a 3.56 composite mean with a strongly acceptable interpretation. This means that the developed system can help with the improvement of the current medical waste management system and lessen the risk of contamination of medical wastes to the employees, patients and in the environment.

IV. CONCLUSIONS AND RECOMMENDATIONS

The data revealed that the current medical waste management system can be improved with the use of technological advancements such the use of machine learning, image processing and robotics. The use of Ultra violet light is suitable on the design that the developers created. But the developers were unable to measure the sanitation level of UV light due to lack of materials for measurement. The system developed revealed that the developed system is helpful in classifying, segregating and sanitizing medical waste for lessening the risk of contamination to other people and in the environment. Arduino Mega Board is suitable in creating systems with image processing program.The Arduino board helps maintaining the functions of the system. And also the data revealed that the use of DCNN in image processing gives a high accuracy in processing and identifying images. The YOLO v5 architecture gives a stable program in creating image processing systems. The use of YOLOv5 can detect and process images with high accuracy and can be improved with more trained data.

After listing and studying the relevant discoveries and assumptions of the developed system, the developers give the following recommendation to the future users and

future researchers that would help develop a more effective and useful improvements of the Medical Waste Classification and Segregation Kiosk Using DCNN for Hospitals. The developers recommend improving the data set for creating a better classification of medical waste for a more innovative wireless connection, future developers can use IoT instead of GSM module for a faster alert message to use a different sanitation method to improve the method that the researchers used future developers can include a different anitation method to be suitable in different medical waste and creating a different design for a suitable improvement in durability of the system. The developers recommend using other DCNN architecture for a higher level of accuracy and handling of large data sets.

REFERENCES

[1] Arora, D., Garg, M., & Gupta, M. (2020). Diving deep in Deep Convolutional Neural Network. 2020 2nd International Conference on Advances in Computing, Communication Control and Networking (ICACCCN). doi:10.1109/icacccn51052.2020.9362907 [Online].Available: https://sci-hub.se/https://ieeexplore.ieee.org/document/9362907

[2] Bian, X., Chen, Y., Wang, S., Cheng, F., & Cao, H. (2021). *Medical Waste Classification System Based on OpenCV and SSD-MobileNet for 5G. 2021 IEEE Wireless Communications and Networking Conference Workshops (WCNCW).* doi:10.1109/wcncw49093.2021.94200. [Online].Available: https://sci-hub.se/https://ieeexplore.ieee.org/document/9420036

[3] Castro,R.C.C.,Magsakay,E.dR.,Geronimo,A.J.S.,Conato,C.,DeniseCruz, J., Alvaran, J. R., &Oblanca, V. J. (2020). Development of Waste ManagementSystemusingtheConceptof"BasuraAdvantage Points" through Artificial Neural Network. 2020 IEEE 12th International ConferenceonHumanoid,Nanotechnology,InformationTechnology, Communication and Control, Environment, and Management (HNICEM). doi:10.1109/hnicem51456.2020.9400123. [Online]. Available: scihub.se/10.1109/HNICEM51456.2020.9400123

[4] Chen, J., Mao, J., Thiel, C., & Wang, Y. (2020). iWaste: Video-Based Medical Waste Detection and Classification. 2020 42nd Annual International ConferenceoftheIEEEEngineeringinMedicine&BiologySociety(EMBC). doi:10.1109/embc44109.2020.917564. [Online].Available: https://sci-hub.se/https://ieeexplore.ieee.org/document/9175645

[5] Das, A. K., Islam, M. N., Billah, M. M., & Sarker, A. (2021). COVID-19 pandemic andhealthcaresolidwastemanagementstrategy–Amini-review.Science of TheTotal Environment, 778, 146220. doi: 10.1016/j.scitotenv.2021.146220. [Online].Available: sci-hub.se/10.1016/j.scitotenv.2021.146220 DCNN

[6] Department of Health (August 16, 2021) – PH Receives Support for Medical Waste ManagementEffortAmidCOVID-19Pandemic. [Online].Available: https://doh.gov.ph/BIHC/BIHC-Updates/ph-receives-support-medical-waste-management-effort-amid-covid19-pandemic

[7] EldanSambatyon.(2020).UPCollegeofEngineeringDevelopsUVCleaning Chamber for PPEs. [Online].Available: https://www.goodnewspilipinas.com/up-college-of-engineering-develops-uv-cleaning-chamber-for-ppes/

[8] Flores,M.G.,&TanJr,J.B.(2019).Literature reviewofautomatedwaste segregationsystemusingmachinelearning:Acomprehensiveanalysis. International Journal of Simulation-Systems, Science & Technology, 20. [Online]. Available: https://ijssst.info/Vol-20/No-S2/paper15.pdf

[9] GaeaKatreenaCabico(August27,2020)– InthePhilippines,MedicalWastepiles up as COVID-19 cases rise. [Online].Available: https://earthjournalism.net/stories/in-the-philippines-medical-waste-piles-up-as-covid-19-cases-rise

[10] Guillermo,M.,Tobias,R.R.,CarloDeJesus,L.,Billones,R.K.,Sybingco,E., Dadios,E.P.,&Fillone,A.(2020).DetectionandClassificationofPublic SecurityThreatsinthePhilippinesUsingNeuralNetworks.2020IEEE2nd Global Conference on Life Sciences and Technologies (LifeTech). doi:10.1109/lifetech48969.2020.1570619075. [Online].Available: sci-hub.se/10.1109/LifeTech48969.2020.1570619075

[11] Zhou, XiangyuYu, Ahmad Alhaskawi,etc. (2022). *A Deep LearningApproachMedicalWasteClassification.* [Online]. Available: https://www.researchgate.net/publication/358489974_A_deep_learning_approach_for_medical_waste_classification

[12] J., Chia, J.H., Sadun, A. S., Wahab, Z. A., & Ali, R. (2021).Automated Recycle Dustbin System with GSM Module for Waste Management. *ELEKTRIKA-Journal of Electrical Engineering*, *20*(2-3), 56- 64. [Online]. Available: https://elektrika.utm.my/index.php/ELEKTRIKA_Journal/article/view/311

[13] Sangkham S. (2020). *Face Mask and Medical Waste Disposal during the Novel COVID-19 Pandemic in Asia Case Studies in Chemical and Environmental Engineering, 100052,* doi:10.1016/icscee.2020.100052. [Online].Available: https://sci-hub.e/https://www/sciencedirect.com/science/article/pii/S2666016420300505

