

Dynamic Bio-Information Image Recognition of Cancer Cell Death based on Parallel Multiple Artificial Intelligence Modules

Ming-Shen Jian^{1,2}, Yi-Ling Ye^{3,*}, Wen-Yu Chung², Wen-Xuan Li³, Yan-Ting Lin³, Bo-Yuan Huang², Javeria Sikandar³, Yu-Jung Chang²

²CCIS Lab., Dept. of CSIE, National Formosa University, Yunlin County, Taiwan 632

³Dept. of Biotechnology, National Formosa University, Yunlin County, Taiwan 632

jianms@nfu.edu.tw¹, yilingye@gs.nfu.edu.tw*

Abstract—

This investigation purpose a unique Dynamic Bio-Information Image Recognition System (DBIRS) built for the real-time monitoring of cancer cell apoptosis produced by available medical therapy. Utilizing advances in microscopy, AI-based image recognition, and parallel computing across distributed edge devices, the proposed system dramatically boosts the precision and efficiency of cellular investigation. By deploying numerous AI modules adapted to distinct cellular states, the system provides automatic, high-accuracy recognition of morphological changes in cancer cells, hence minimizing the need on manual procedures. This technique offers remote monitoring and fast data processing via cloud integration, permitting continuous observation and timely intervention. The system's efficiency is proven through trials on K-562 cells, where it attained a recognition accuracy of 97.41%. These outcomes underline the potential of the proposed method to refine cytotoxicity assays, delivering a strong tool for increasing the efficacy and safety of immune cell treatments in clinical and research settings.

Keywords— Image Recognition, Artificial Intelligence, Cellular Analysis, Cancer Cell

I. INTRODUCTION

Bio-information is the hot research topic recently. Based on the improvement of the image resolution, microscope hardware, and computing resources, etc., more data obtaining, analysis, and management is possible. To observe the cell status, find the related data of cell, etc., could be easier than before. Based on the interdisciplinary integration of knowledge and systems, more contributions can be done to the medical treatment or biological experiment observation.

The emerging cancer treatment therapy-immune cell therapy has been developed and proposed. Natural killer cell (NK) therapy is a relevant topic discussed for cancer treatment [1]. NK cell therapy or treatment first draws the patient's blood. Then, the laboratory or system separates and purifies the NK cells. Through cell culture technology and the

addition of specific cytokines, after about 14 days, NK cells are possibly proliferated and activated in large quantities. Finally, the grown and activated NK cells are injected back into the original patient's body to begin killing cancer cells. Therefore, immune cell therapy must pay special attention to the cell quality and safety control. It means that the cell survival rate would be a very important indicator in immune cell therapy or cell cytotoxicity experiments. Now the NK cell cytotoxicity assay was done by flow cytometry [2], but this assay was measured after four hours culturing, collecting, staining, and flow cytometry analysing. For improving the analysing efficiency, strategies such as label free, real time analysing, and AI management are eagerly needed in this assay. By continuously observing the real-time morphological changes of cells at different times through a microscope, images of cell survival and cell death can be found. However, it causes the need of long time and manual operation.

Since the physical computing resource is improved, to integrate the artificial intelligence about image recognition would be the possible solution for automatic cell observation. First, the AI image recognition algorithm is more convenient and faster than traditional manual analysis methods. Second, it is not affected by the operating environment, operators, and analytical instruments or equipment.

However, different status of the cells would be possible. Training the corresponding AI modules for enhance the recognition accuracy of cell various statuses is required. Considering the possible status of various cell characteristics such as the changing of

size, shape, color, etc., to independently and individually identify and recognise the various status of cells would be the possible solution for AI module training.

To individually train the AI module for image recognition, dividing the training missions or data into multiple computing devices could be the solution [3, 4].

In this research, the Dynamic Bio-Information Image Recognition of Cancel Cell Death based on Parallel Multiple Artificial Intelligence Modules is proposed for the images or streaming recognition of the Cancel Cell Death caused by the NK cell. Based on the remote devices and program, the laboratory observers needn't to spend whole time inside the laboratory[5]. The remote device could upload or streaming the image data to the cloud platform for the AI progressing. The contributions of the proposed system are:

1. The remote device such as microscope can upload the current cell image immediately for the further AI progressing. Time delay and manual operation can be reduced.
2. Based on the trained AI modules, the corresponding cells in the image can be recognized. It means that the counting and evaluation of the current cells can be done. The basic rule for recognition between different images could be the same. Experimental measurements are consistent
3. Recognition module of various cells could be individually progressed. The AI workload can be distributed into multiple edge computing devices.
4. Based on the multiple trained AI modules, no additional detection reagents in treatment or laboratory are required. The proposed system can reduce the cytotoxicity interpretation time.

II. RELATED WORKS

In the process of killing cancer cells, first, the NK cells approach the cancer cells. NK natural killer cells secrete perforin, which forms holes/pores in the cell membrane of cancer cells. Then, the NK natural killer cells secrete a protease from the pores, causing the cancer cells to dissolve and shrink. Finally, the NK natural killer cell could cause cancer cells death[6].

To understand the cytotoxicity ability and quality of the cells, the cell survival rate about the ratio of the cell survived and died can be used. The methods for evaluating the cell survival rate including using trypan blue, MTT, CCK-8 or flow cytometry were proposed. However, these methods are time-consuming and human resource. MTT takes 4 to 6 hours for the reagents to react. The pre-processing of collecting cells before analysis by flow cytometer takes more than one hour. Moreover, adding additional reagents for testing may cause additional cytotoxicity and cell death. As a result, the immediate cell survival rate cannot be accurately displayed. Validation of three feasible trypan blue cell counting methods (manual, semi-automatic and automatic) is mainly discussed [7, 8]. Manual cell counting requires the use of a hemocytometer under a microscope and counting with the eye. This method is time-consuming and subject to variability due to the operator's level of expertise. Semi-automated method, such as the Countess system, introduces some automated steps into the counting process. However, some steps still require manual operations, such as sample preparation and loading. Automated methods, such as Vi-CELL XR, utilize advanced imaging technology and software to automate the entire cell counting process. It provides more consistent and reliable results than manual and semi-automated methods. Since the original data would be the images from the microscope, adopting the AI application for the cell recognition and counting would be the solution of automated methods with consistent and reliable results.

However, to progress the A.I. applications such as image recognitions, data training, etc., computing resources are required. Instead of deploying the main server with huge computing resource, parallel progressing and distributed edge device system based on the modular AI computing jobs was proposed[3]. First, the objects for recognition should be labelled and segmented. By collecting huge data of the labelled objects, the training for object recognition can be achieved [9, 10].

After training, the module or characteristics of the labelled object can be found.

Recently, YOLO algorithm is generally used in various object recognition systems [3, 5, 9, 11-13]. Based on YOLO algorithm, the objects included in

the image or photos can be recognized according to the pre-trained module. For example, the music instrument can be detected based on the trained spectrum[11]. By collecting the image of the object and YOLO algorithm training, the under the water object can be recognized[12]. Considering the color of objects from the background, the recognition based on YOLO algorithm could still work [13]

After recognition, the found objects could be represented as the text plain content with the coordinate position information. It means that to give the description of the image such as the total amount of the recognized object, the size or area of the object segmentation, the color or brightness of the object, etc., becomes more possible after object recognition.

III. PROPOSED SYSTEM

In this research, using a microscope to continuously observe the immediate morphological changes of cells at different times, we can find out the correlation between cell survival and cell death for image identification.

In experiments simulating NK cells attacking K-562 blood cancer cells, the industry usually uses T drugs as a positive control group. Through testing under the positive control group experimental conditions in the natural killer cytotoxicity test, we can observe the status of K-562 cells which are treated by T drugs. K-562 cells will sequentially show enlargement, cell membrane rupture and shrinkage. Through the long-time observation and photo taking, each phase or status of cells are marked and selected to establish an AI image recognition algorithm database. These various images of marked and selected cells are used to train the AI image recognition algorithm.

Since the K-562 cells will sequentially show enlargement, cell membrane rupture and shrinkage, to divide the images into several corresponding groups is important. In order to summarize the changes in cells, we divided the obtained cell photos into three groups: initial group, transition group, and evaluation group. Multiple single-cell images of each group could be used as the training data for the AI module.

Considering the training time and the required computing resource, we would train the AI modules corresponding to three groups individually. In other

words, we will build three independent AI modules for cell recognition. However, since the K-562 cells will sequentially change, some cells in the same image would be recognized as one group instead of another. It means that cells of different groups would be all in the same photo. Therefore, to parallel progress the AI recognition for the cells of different groups is needed since there are three independent AI modules.

For parallel progressing of the AI recognition, the proposed system delivers the same input image to three independent edge computing devices. Based on the YOLO algorithm and system environment, the image recognition process can be packaged into the Docker container for rapid deployment [14]. Following figure presents the structure of the proposed system. The remote microscope as the Internet of Things (IoT) device provides the image or streaming to the main server. The operator should on demand choose the corresponding trained AI modules for the cell recognition. Therefore, the main server would input the chosen multiple AI modules into individual Docker container [4] in advance. When receiving the recognition request such as the cell image, the main server would deliver this image file and container with chosen AI module to individual edge device for the recognition progressing. Hence, the cell recognition processes based on various and multiple AI modules could be parallel progressed by individual edge device with the GPU resource. The recognition results would be replied from the edge devices to the main server.

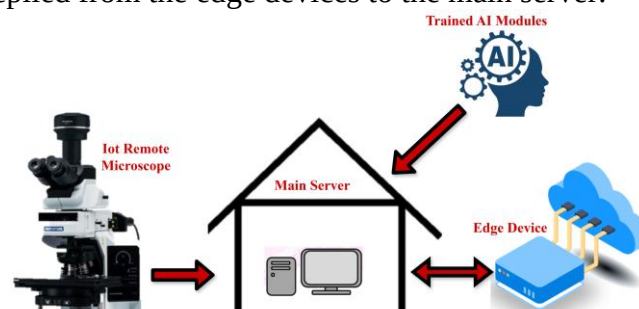


Figure 1. The structure of the proposed system based on Parallel Multiple Artificial Intelligence Modules

After receiving the responses from multiple edge devices, the recognition results should be merged into single recognition report. The recognition results include the information corresponding to

each recognized cell such as coordinate position, segmentation size, etc. Since the recognition results come from different AI modules for the cell recognition, without the doubt, some cells may be recognized by multiple AI modules. In other words, one cell in the same image would be recognized by multiple AI modules due to the similar probability.

When merging all results from multiple edge devices, the repeated identification or recognition situations should be considered. If one cell is only recognized by only one type of pre-trained AI module, the type of the cell can be decided. IN opposition, if one cell is recognized by more than one pre-trained AI module, this specific cell would be marked as the “undetermined”. It means that the additional manual operation is needed. First, if there exists the undetermined cell, the proposed system could set the calculating function for the value of similar probability from different AI modules. If the differences between the values of similar probability is larger than the defined threshold value, the recognition type with higher similar probability would be the final output. Otherwise, the system user should decide the correct recognition of this cell. Second, this manually recognized cell image would be added into the training data of the corresponding AI module. In other words, every time an undetermined cell found, the corresponding AI module should be trained again for enhance the recognition accuracy.

IV. VERIFICATION RESULTS

To verify the proposed system structure, the cell image recognition is deployed based on YOLO which is packaged in the Docker container.

In the beginning, we culture the cell for the training data. The cell name used in the experiment is K-562 cell (BCRC-60007). The culture medium used in the experiment is RPMI-1640. IoT device as experimental equipment and instruments is the networked digital inverted fluorescence microscope. T drug concentrations are 0.1% (positive control group) and 0% (negative control group) respectively. K-562 cell concentration is 2.75×10^5 cells/ml. Then, video recording can be done by inverted fluorescence microscope. Finally, we can obtain various images of the K-562 cell corresponding to different time and status.

According to these images, we can start the AI module training and development as follows:

1. Manually use labeling application to label and segment normal living cells (find the length and width of normal living cells). Figure 2 shows the labelling results done by the professional researcher. Only the cell satisfies the conditions of specific status could be labelled.

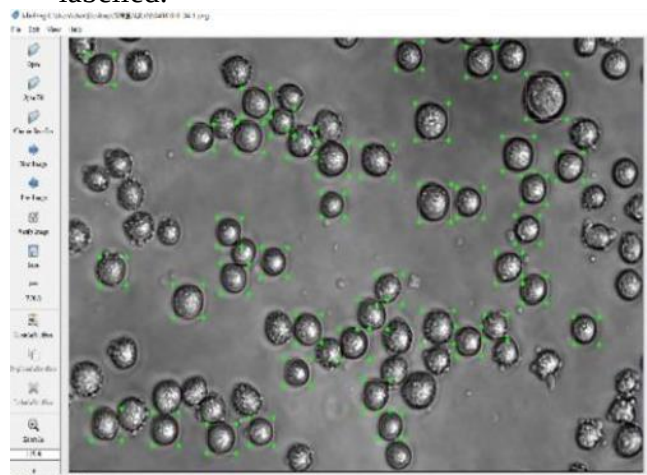


Figure 2. The labelling result of the K-562 cell corresponding to specific status in labeling application

2. Give the data of labelled cell to AI module container for learning. Since there would be different labels corresponding to the status of cell, the AI training related to each label would be individual and independent on edge device. Figure 3 presents the text data corresponding to each labelled cell in the image.

	Class	Images	Labels	P	R	mAP _{0.5}	mAP _{0.5:0.95}	100%	16/16	00:15:00:00
Epoch 4/9	all	128	7808	0.179	0.246	0.0678	0.0114			
	gpt_waa	box	obj	cls	total	labels	img_size			
	1.445	0.05496	0.03528	0	0.09225	456	320	100%	32/32	01:00:00:00, 1.90s/it
	Class	Images	Labels	P	R	mAP _{0.5}	mAP _{0.5:0.95}	100%	16/16	00:15:00:00
	all	128	7808	0.319	0.369	0.185	0.0299			
Epoch 5/9	gpt_waa	box	obj	cls	total	labels	img_size			
	1.445	0.05417	0.03644	0	0.09281	396	320	100%	32/32	00:59:00:00, 1.86s/it
	Class	Images	Labels	P	R	mAP _{0.5}	mAP _{0.5:0.95}	100%	16/16	00:15:00:00
	all	128	7808	0.384	0.557	0.347	0.074			
Epoch 6/9	gpt_waa	box	obj	cls	total	labels	img_size			
	1.445	0.05499	0.03682	0	0.09181	422	320	100%	32/32	01:00:00:00, 1.88s/it
	Class	Images	Labels	P	R	mAP _{0.5}	mAP _{0.5:0.95}	100%	16/16	00:15:00:00
	all	128	7808	0.369	0.393	0.23	0.0414			
Epoch 7/9	gpt_waa	box	obj	cls	total	labels	img_size			
	1.445	0.05191	0.0383	0	0.09021	337	320	100%	32/32	01:00:00:00, 1.88s/it
	Class	Images	Labels	P	R	mAP _{0.5}	mAP _{0.5:0.95}	100%	16/16	00:15:00:00
	all	128	7808	0.267	0.328	0.169	0.0311			
Epoch 8/9	gpt_waa	box	obj	cls	total	labels	img_size			
	1.445	0.05125	0.03668	0	0.08793	620	320	100%	32/32	00:59:00:00, 1.97s/it
	Class	Images	Labels	P	R	mAP _{0.5}	mAP _{0.5:0.95}	100%	16/16	00:17:00:00
	all	128	7808	0.346	0.607	0.316	0.0574			
Epoch 9/9	gpt_waa	box	obj	cls	total	labels	img_size			
	1.445	0.04395	0.03351	0	0.07747	451	320	100%	32/32	00:11:00:00, 2.45s/it

Figure 3. The text data corresponding to each labelled cell

3. The AI modules corresponding to status of cell are developed independently. However, the overlap of different cell recognition results due to the size or shape of the cell would happen.
4. When receiving the new image, single image would be parallel delivered to multiple edge devices

with different AI modules. In this research, the edge devices could be the 4GB memory NVIDIA Jetson Nano embedded systems with 128-core NVIDIA Maxwell GPU. These Jetson Nano embedded system devices are used as the computing nodes for the AI image recognition progressing. Using Jetson Nano would be only 14% cost lower than a laptop. Hence, multiple AI modules would be possible for deployed and progressed on different Jetson Nano edge devices with lower cost.

5. The recognition results received by the main server from the edge devices. The repeated recognition requires further manual operation. Finally, we can obtain the cell survival rate and calculate the drug killing ability.

Figure 4 shows the recognition result in continuous observation of the K562 cell with T dug. The cell can keep moving and the proposed system can continuously recognize each cell individually with the high accuracy. Figure 4 (a) shows the cell image of the laboratory at beginning and (b) shows the dead cell which is not misidentified after 2 hours. The accuracy of cell recognition is 97.41%

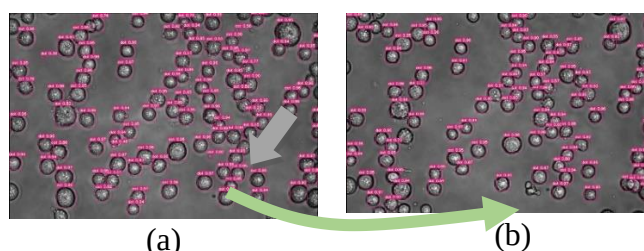


Figure 4. The observation data corresponding to K-562 cell (a) at beginning and (b) after 2 hours.

V. CONCLUSION

According to the proposed parallel multiple AI modules, the data corresponding to various status of the specific cell could be individually used for AI training and module development. The rarely repeated recognized cell could be manually identified and further trained for enhancing the recognition accuracy.

The results of dynamic bio-Information image recognition can be used to evaluate and estimate the cancer cell poisoning status caused by medicine. Based on the analysis of the data, the accuracy of cell recognition can be 97.41%.

Acknowledgement

We thanks the techniques and equipments supported by Centre of Precision Health and LOHAS Innovation; CPHLI, NFU. Yi-Shan, Wu, Dept. of Biotechnology, National Formosa University, provide the opinion and assistance for cell image recongnization.

REFERENCES

- [1] E. Vivier, L. Rebuffet, E. Narni-Mancinelli, S. Cornen, R. Y. Igarashi, and V. R. Fantin, "Natural killer cell therapies," *Nature*, vol. 626, no. 8000, pp. 727-736, 2024, doi: doi.org/10.1038/s41586-023-06945-1.
- [2] F. Kandarian, G. M. Sunga, D. Arango-Saenz, and M. Rossetti, "A flow cytometry-based cytotoxicity assay for the assessment of human NK cell activity," *JoVE (Journal of Visualized Experiments)*, no. 126, p. e56191, 2017, doi: <https://dx.doi.org/10.3791/56191>.
- [3] H.-Y. Huang, M.-H. Tsai, and M.-S. Jian, "Multiple Merged Structures Based on Image Recognition for Converting Application of Natural Language Artificial Intelligence Service," in *2024 26th International Conference on Advanced Communications Technology (ICACT)*, 2024: IEEE, pp. 158-162, doi: <https://doi.org/10.23919/ICACT60172.2024.10471930>.
- [4] N. Janbi, I. Katib, and R. Mehmood, "Distributed artificial intelligence: Taxonomy, review, framework, and reference architecture," *Intelligent Systems with Applications*, vol. 18, p. 200231, 2023, doi: <https://doi.org/10.1016/j.iswa.2023.200231>.
- [5] M.-S. Jian, Y.-Z. Luo, P.-W. Wang, and T.-Y. Lai, "Cloud and Edge Computing Based Movable 3D Dynamic Image Recognition and Analysis Layer System for Remote Biological Laboratory," in *2023 25th International Conference on Advanced Communication Technology (ICACT)*, 2023: IEEE, pp. 429-436, doi: <https://doi.org/10.23919/ICACT56868.2023.10079325>.
- [6] I. Prager and C. Watzl, "Mechanisms of natural killer cell-mediated cellular cytotoxicity," *Journal of leukocyte biology*, vol. 105, no. 6, pp. 1319-1329, 2019, doi: <https://doi.org/10.1002/JLB.MR0718-269R>.
- [7] D. Cadena-Herrera *et al.*, "Validation of three viable-cell counting methods: Manual, semi-automated, and automated," *Biotechnology Reports*, vol. 7, pp. 9-16, 2015, doi: <https://doi.org/10.1016/j.btre.2015.04.004>.
- [8] V. Peli *et al.*, "Validation of an automated viable cell counting assay for GMP manufacturing of human induced pluripotent stem cells," *Biochemical Engineering Journal*, vol. 196, p. 108953, 2023, doi: <https://doi.org/10.1016/j.bej.2023.108953>.
- [9] M. Mahendru and S. K. Dubey, "Real time object detection with audio feedback using Yolo vs. Yolo_v3," in *2021 11th international conference on cloud computing, data*

science & engineering (confluence), 2021: IEEE, pp. 734-740, doi: <https://doi.org/10.1109/Confluence51648.2021.9377064>.

[10] A. Torralba, B. C. Russell, and J. Yuen, "Labelme: Online image annotation and applications," *Proceedings of the IEEE*, vol. 98, no. 8, pp. 1467-1484, 2010, doi: <https://doi.org/10.1109/JPROC.2010.2050290>.

[11] C. Dewi, R.-C. Chen, and Y.-T. Liu, "Similar music instrument detection via deep convolution YOLO-generative adversarial network," in *2019 IEEE 10th international conference on awareness science and technology (iCAST)*, 2019: IEEE, pp. 1-6, doi: <https://doi.org/10.1109/ICAWS.2019.8923404>.

[12] X. Wang, X. Jiang, Z. Xia, and X. Feng, "Underwater object detection based on enhanced yolo," in *2022 International Conference on Image Processing and Media Computing (ICIPMC)*, 2022: IEEE, pp. 17-21, doi: <https://doi.org/10.1109/ICIPMC55686.2022.00012>.

[13] W. Yijing, Y. Yi, W. Xue-fen, C. Jian, and L. Xinyun, "Fig fruit recognition method based on YOLO v4 deep learning," in *2021 18th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON)*, 2021: IEEE, pp. 303-306, doi: <https://doi.org/10.1109/ECTI-CON51831.2021.9454904>.

[14] D. Reis, B. Piedade, F. F. Correia, J. P. Dias, and A. Aguiar, "Developing docker and docker-compose specifications: A developers' survey," *Ieee Access*, vol. 10, pp. 2318-2329, 2021, doi: <https://doi.org/10.1109/ACCESS.2021.3137671>.



Ming-Shen Jian was born in Kaohsiung City, Taiwan in 1978. He received the B.S. from the National Chiao Tung University, HsinChu, and Ph.D. degrees in Computer Science and Engineering from the National Sun Yat-sen University, Kaohsiung, Taiwan in 2007. From 2018, he was an Associate Professor and director with the National Formosa University Cloud Computing and Intelligent System Laboratory. Currently he is also an IEEE Senior

Member. Since 2009, he has been an Assistant Professor with the Computer Science and Information Engineering Department, National Formosa University. He is the author of four books, more than 50 articles, and at least 15 invention patents. His research interests include IOT development and application, Big Data, Optimal Solution, Intelligent System, and Cloud Computing. He was a Secretary of the Taiwan Association of Cloud Computing. Dr. Jian was a recipient of the IEEE sponsored international conference Paper Award in 2016, 2017, and 2018.



Yi-Ling Ye was born in Tainan City, Taiwan in 1971. She received her B.S. degree in Department of Clinical Laboratory Sciences and Medical Biotechnology, College of Medicine, National Taiwan University in 1993. She received her M.S. and Ph.D. degrees in Graduate Institute of Immunology, College of Medicine, National Taiwan University in 1995 and 2002, respectively. During 1999 to 2007, she was used to teach at Department of Medical Science and Biotechnology, Chung Hwa University of Medical Technology. From 2008 to now, she was Professor and director with the National Formosa University Molecular Immunology Laboratory. Her research interests lie on cellular immunology and immune regulation in disease.



Wen-Yu Chung currently is a bachelor degree student of Dept. Computer Science and Information Engineering at National Formosa University. Her current research interests are in the area related to object recognition and segmentation, and image progressing. She joins the Cloud Computing and Intelligent System Lad. (CCIS Lab.) from 2022.



Wen-Xuan Li is a master's student in the Department of Biotechnology at National Formosa University. Her research interests focus on the identification and analysis of cell death patterns in various leukemia cells. She joins the Molecular Immunology Lab (MI Lab) from 2022.



Yan-Ting Lin is currently a bachelor's degree student in the Department of Biotechnology at National Formosa University. His research interests focus on the identification and analysis of cell death patterns in K-562 leukemia cells. He joined the Molecular Immunology Lab (MI Lab) in 2023.



Bo-Yuan Huang currently is a bachelor degree student of Dept. Computer Science and Information Engineering at National Formosa University. His current research interests are in the area related to Cloud Computing and Docker container services, security, and intelligent system. He joins the Cloud Computing and Intelligent System Lad. (CCIS Lab.) from 2021.



Javeria Sikandar is a master's student in the Department of Biotechnology at National Formosa University. She is a Medical Lab Technologist and a graduate of Children's Hospital Lahore, Pakistan, with strong academic credentials. Driven by her passion, she pursued a position as a Research Assistant in Hemato-Technology at the University of Health Sciences, Lahore, Pakistan. She has over three years of experience working in reputed medical laboratories.



Yu-Jung Chang is a master's student of Dept. Computer Science and Information Engineering at National Formosa University. Her current research interests are in the area related to medical information engineering and IoT device designing. She joins the Cloud Computing and Intelligent System Lad. (CCIS Lab.) from 2024.