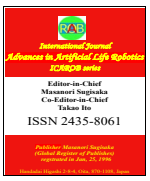
SUGISAKA MASANORI

Journal of Advances in Artificial Life Robotics
Vol. 4(4); March (2024), pp. 222–229
ON LINE ISSN 2435-8061; ISSN-L 2435-8061
https://alife-robotics.org/jallr.html



Research Article

Bridging the Gap Between Industry 4.0 (IR 4.0) and an Undergraduate Industrial Automation and Robotics Degree Program to meet the Robotic Road Map of a Developing Nation

M. K. A. Ahamed Khan[1], Mastaneh Mokayef[1], Ridzuan, A[1], MHD Amen Summakieh[1], Sew Sun Tiang[1], Wei Hong Lim[1], M. Suresh[2]

[1]*UCSI University, Faculty of Engineering, Taman Connaught, 56000 Malaysia*
[2]*Department of Electrical and Electronics Engineering, Murugappa Polytechnic College, Chennai, Tamil Nadu, India*

ARTICLE INFO

Article History

Received 23 November 2023

Accepted 16 August 2024

Keywords

Industrial automation
Robotics
Curriculum development
Undergraduate
Control
Drone
Roadmap
Economy

ABSTRACT

The advent of Industry 4.0 (IR 4.0) has completely changed the landscape of many manufacturing and industrial sectors through the proper integration of modern digital technologies such as the computer science, Internet of Things (IoT), artificial intelligence (AI), robotics, automation, cyber physical systems, cybersecurity, data mining and data analytics. This tremendous change necessitates a paradigm shift in many of the educational programs, especially in one of the core pillars of IR 4.0 which is called Robotics and Automation program to equip the future workforce with relevant skills and advanced knowledge. This paper explores how to bridge the gap between an undergraduate Industrial Automation and Robotics degree program with the current educational curricula and the demands of IR 4.0 to meet the Robotic Road Map of a developing nation.

1. Introduction

The Robotics is an interdisciplinary course that integrates mechanical, electrical and electronics engineering, computer science, cognitive science, design, simulation, construction, and operation of robots. It also encompasses relevant robotic fields such as computer and machine vision, control, and automation systems as well as all types of robots and its technologies, including but not limited to humanoid, co-bots, robotic arm and manipulators, mobile robots, drones, tele – operated and soft robots. In order to have a single course that can have multi-disciplinary combination of various fields of engineering, automation and robotics is the most ideal course which can be offered to the engineering students in the degree level. Many institutions, taking the robot-designing course at the Stanford, MIT and Cambridge University [1], start offering various courses in robotics and automation engineering that comes along with advanced laboratories. During robotic building techniques it's very important to implement machine intelligence and decision-making concepts. Many degree level courses in Artificial Intelligence rely on these concepts [2], [3].

In any developing nation, in order to bridge the gap between IR 4.0 and Industrial automation and robotic degree program, it is important to follow the key steps that will guide one through the complete process.

- Understand IR 4.0 Principles – this covers the key areas like Interconnectivity - means the use of Internet of Things (IoT) to connect devices and systems, Information transparency, Utilization of AI and machine learning to assist in decision-making and problem-solving,

Corresponding author's E-mail: Mohamedkhan@ucsiuniversity.edu.my, URL: https://www.ucsiuniversity.edu.my/

empower systems to make decisions autonomously.

- Focus on the goals, requirements and the key performance indicators of Automation and Robotic programs.
- Evaluate the current infrastructure, technologies, and processes.
- Develop a road map that includes timelines, resource allocation and budget considerations.
- Introduce the correct technologies like IoT, robotic systems, AI, cloud computing and machine learning.
- Design and prototype projects using simulation tools to test, model and optimize the processes.
- Combine physical systems with digital technologies and make sure good communication between humans, systems, and machines.
- Provide good compatibility between devices and systems using protocols and standards
- Provide robust cybersecurity measures to protect data
- Train and upskill the workforce and encourage continuous learning
- Monitor and optimize the robotics systems
- Encourage innovation and stay updated with the latest trends in IR4.0

For socio – economic advancement, robotics is the key driving and enabling technologies that addresses the major challenges involving Industry revolution 4.0, rise of the innovation- led knowledge intensive economy and the arrival of mega trends such as rabid urbanization, social change, technological breakthrough, climate change and economic power shift.

In today's fast changing world, technologies advances at break through speeds. Almost in all the applications the application of Robotics and AI is evident. The industrial robot has reshaped the entire manufacturing landscape through years performing duties unsuitable for humans. In 2025 the drone industry could be worth of $250 billion. The virtual and augmented reality technology could be worth of $ 150 billion in 2024.

2. Planning process

Though many efforts were taken by various authors considering the different problems looking in to the present and future in different disciplines of education [4], [5]. It is understood that there is no one bridge the gap between IR 4.0 and the Industrial robotics and automation program. Looking into the regional employment demand it is not only vital to pay consideration to the graduate study needs, but also to bridge the gap between IR 4.0 and the program. It is important to practice careful discernment regarding the fast trends in technological changes happening today. As an industry in order to meet their essential requirements that makes regular demands of undergraduate preparation [6], [7], [8] students educational paths changes, also sometimes due to the changes and demands in the trade which depends on the fast-changing technologies, it is no easy to understand the proper educational pattern. Engineering students must have a strong base in fundamental concepts which gives them a better understanding of the entire program, for if a program is too specialized, the range of opportunities available for graduates will be compromised. While investigating the gap between new program and IR 4.0 it became clear that close ties to the subject areas associated with machine learning and artificial intelligence, wide variety of advanced transducers, interfaces was critical is essential. Also the meetings (both group and individual) with representatives drawn from various robotics and automation Industries and industrial advisory boards. Both the professionals from industry and academic has been asked to identify the gap between educational needs (industrial automation and robotics) based on the large and clearly identified trends among industries and the main pillars of Industry revolution 4.0. The second method involved is the exploration of the talent development focusing on the following factors:

- Number of Students in technical, STEM related studies
- Number of Technical and vocational schools
- Skilled required for robotics technicians
- Certificate and training programs
- Robotics in school and higher secondary school curriculum
- Robotic competitions
- Number of polytechnic colleges offering robotic related courses
- Research funding both national, international and industry
- Facilities and equipment's for robotic research
- Research publications
- Higher learning institutions offering post graduate studies in the area of robotics and automation
- Commercialization and innovation
- High quality text books written by eminent scholars, top tier engineering journals, well equipped technical libraries in universities.

A roadmap which shows the future development and needs of a developing nation must be generated at the end of the planning period. This also must be in line with the new curriculum. The extreme environments and their respective control systems needs careful analysis of computer science, automation, IOT, and data storage.

These topics traditionally constitute the core of the IR 4.0 [9], [10].

A multifaceted evolution approach is essential to compare the effectiveness of a robotic program in relation to IR 4.0. This involves both assessing the curriculum of the planned robotic degree program also the hands-on learning opportunities [11], [12]. More importance should also begiven for examining faculty expertise, research collaboration with industry, graduate success, and industry consultancy. By continuously gathering and analyzing feedback from various stakeholders, the program can adapt and evolve to meet the ever-changing demands of the IR 4.0 landscape.

Table 1 Proposed Subject Distribution of IART to meet the demand of IR4.0

NO	CATEOGORY	SUBJECTS	HC	%	HCT	%
1	Core Technical subjects	Automation Technology	10	7.63	29	22.12
		Robotics	7	5.34		
		Mechatronics	4	3.05		
		Manufacturing systems	8	6.10		
		Data science and analytics	2	1.52	2	1.52
2	Interdisciplinary Subjects	• Information Technology • Artificial Intelligence and Machine Learning • Sustainable and Green Technologies • Project Management and Business	30	22.90	30	22.90
3	Practical and hands on training	Lab work and simulation	30	22.90	64	50.85
		Industry projects and internship	30	22.90		
		Workshops and seminars	4	3.05		
4	Soft skills and development	• Communication skills • Teamwork and leadership • Problem solving and critical thinking	6	4.58	6	4.58
	TOTAL CREDITS HOURS		**131**		**131**	**100%**

3. The development of Bachelor of Engineering Technology programme to bridge the gap.

The development of Bachelor of Engineering Technology Programme in Industrial Automation and Robotics Technology to bridge the gap with IR4.0 will be considered in this section during their four-year study. Student takes a minimum of 131 credit hours for the entire semesters. From Table 1 it can also be seen that the core technical subjects are composed of 23.64%, interdisciplinary subjects 22.90%, practical and hands-on training 50.85% and soft skills and development 4.58%.

The total credits hours are 131. Interdisciplinary subjects should come from other faculties like computer science and management. Practical and hands-on training can be carried out in the laboratories and the industries involved in offering inter training for the students. Soft skills and development can be taken care by the language and general subject department. Various subjects are offered in different semesters from year 1 to year 4. Subjects offered in semester 1 is shown in Table 2.

Credit hours of the entire coursework (over 8 semesters) is divided among four general categories of classes. The four areas are core technical subjects, interdisciplinary subjects, practical and hands on training, soft skills and development as shown in Table 1, where HC is the hours credit and HCT is the credit hours total.

Table 2 Subjects of 1st Semester

No	Code	Subjects	Credit Hours	No. of Hours Per Week	LEC	TD	P	No of Hours Per Sem
1	IAUT 3412	Fundamentals of Automation	3	2	1		2	54
2	EDR 3012	Basic Engineering Drawing	2	3	2			54
3	ELE 3112	Introduction to Electrical	2	3	1		2	54
4	SAM 3012	Introduction to Safety Management	1	3	2			36
5	CIT 1002	Circuit Theory 1	3	2	3			54
6	ELP 1004	Electrical Power	3	3	3		2	54
7	MAT 3112	Basic Mathematics	3	3	1	1.5		45
8	SAD 3012	Static and Dynamics	3	3	1	1.5		45
			20	22	14	3	4	396

From Table 2, it can see that the subjects offered in semester 1 are 'Fundamentals of Automation', Basic Engineering Drawing, Introduction to Electrical, Safety Management, Circuit Theory 1, Electrical power, 'Basic Mathematics' and 'Statics and Dynamics'. Considering one of the subjects 'Electrical power', it is a 3 credits hours subject where 3 hours are considered as main contact hours between students and lecturer and 2 hours for practical. All together 54 hours is given for this subject. Lecturers and students were engaged with 396 hours of contact.

Analyzing the topics inside different subjects is important. Considering this matter, a typical higher-level subject which is usually offered in year 3 or 4 is discussed below. The title of the subject is known as 'Control System'. 3-credit hours is given for this core subject. The core objective is to provide students with broad knowledge on mathematical modelling of various systems like electrical, mechanical, hydraulic and pneumatic, also the design concept of Control systems. This control system subject has a three-hour lab session combined with two and half hours of lecture and tutorials per week. Both the tutorials and lecture classes are focused on feedback control systems fundamentals, while the laboratory portion teaches 'hands on' simulation techniques to study both time and frequency domain of the first order and second order systems. The course offers classical design, that covers system stability and stability analysis, design of compensators. Text books are available in the library resources. Recommended Text books are authored by Ogata K and Kuo B.C [6] or Franklin G F [7].

The course contents are listed below:

- Mathematical Modelling. This part deals with writing differential equations of various systems, transfer functions, State-space representation. Block diagrams, block diagram reductions. Signal flow graph. Distributed parameter system.
- Dynamical systems time response: Model solution obtaining.
- Stability: Analysis of stability using different methods.
- Control feedback: Fundamentals of control feedback systems. Error correction using different controllers.
- Controller design: Using plot technique, steps in obtaining various plots. Controller design, controllability and observability.
- Analysis in frequency and time domain
- Compensators.

4. Data Collection

To close the gap between IR 4.0 and the offered Program it is important to collect the student data to compare and analyses various aspects of the individual student performance and engagement. This can be achieved by the workflow example listed below.

- **Data Collection**: Collect semester grades, competition results, attendance records, and feedback surveys.
- **Data Organization**: Create a spreadsheet categorizing data by student, demographic, and performance metrics.
- **Data Analysis**: Use Excel to calculate average grades, attendance rates, and identify correlations (e.g., higher attendance correlates with better performance).

- **Implementation**: Based on the analysis, introduce coding workshops for students struggling with programming.
- **Monitoring**: Track the performance of students who attended the workshops to measure improvement.

An example of the data collected from a university offering a four-year Degree program in Industrial Automation and robotics that needs to close the gap with IR 4.0 is listed and divided into many sections, i.e., the first section shows student complete profile which details the intake of the student and completion of the degree program, student performance in the second section and in the third section student employment is discussed.

4.1 The profile of the student

Profile of student that shows the student intake and graduation is given in Table 5.

Table 3 Profile of the student

Intake of the year	M	F	TOTAL
January 2021	50	28	78
January 2022	39	6	45

Final Semester	M	F	TOTAL
January 2021	44	24	68
January 2022	35	6	41

Number of students completed with Pass	M	F	TOTAL
Intake January 2021	40	21	61
Intake January 2022	32	4	36

Fail to complete the degree	M	F	TOTAL
January 2021	4	3	7
January 2022	3	2	5

From Table 3, for the January 2021 batch 44 students registered for the final semester, out of which 40 manage to get the graduation and 4 fail to graduate. For the batch January 2022 out of 35 students, 32 manage to get the graduation, 3 fail. Overall 80 percent of the students managed to get more than 70% marks in core technical subjects and scored 72% in Inter disciplinary subjects, scored 100% in practical and hands on training. In the category- soft skills and development overall all the students managed to pass and achieve good results more than 90%. This is mainly because of the lab facilities and the training conducted for the students to enhance the skill. Results are given based on the report submission. From the above information it's clear that the Robotic degree program designed meets the need of IR 4.0.

The age group of batch January 2021 and batch January 2022 is shown in Table 4.

Table 4 Age Group

Age	28	27	26	25	24	23	22	21	Total
Intake January 2021	6	7	3	20	12	11	13	6	78
Intake January 2022	2	1	9	6	5	4	6	12	45

From Table 4, the students age group those who enrolled in first semester of the year 2021 and 2022 varies from 21 to 28 years. The initial enrolment is 78 and 45 for the first and second batch. The higher age group is the reflection of the students having some Industrial experience.

4.2 Student performance

The final semester results for the batch January 2021 and January 2022 is shown in Table 5.

Table 5 Final Semester Results

Category	DN	BK	Total
Intake January 2021	12	49	61
January 2022	14	22	36

DN	>3.6
BK	2.00-3.59
PK1	<2.00 1st time
PK2	<2.00 2nd time
GK	<1.00 or <2.00 3rd time
INCO	Incomplete semester

Table 5 shows the overall student performance in two different intakes, in January 2021, 12 students come in the class DN and 49 students come in BK class. Total number of students passed is 61.
In January 2022, 14 students come in DN class and 22 students come in BK. Total number of students passed is 36.
The final CGPA results for the batch January 2021 and batch January 2022 is shown in the Table 6.

Table 6, shows the final semester results. For January 2021, CGPA of 12 students falls in the range 2.00 to 2.50, 26 students come in 2.50 to 3.00 range, 11 students 3.00 to

3.59 and finally 12 students rated above 3.6 CGPA. Total passed is 61.

Table 6 Final Semester Results

CGPA	<2.00	2.00-2.50	2.50-3.00	3.0-3.59	>3.6	Total
Batch January 2021		12	26	11	12	61
Batch January 2022		6	10	6	14	36

In batch January 2022, 6 students have their CGPA ranging from 2.00 to 2.50 and 10 students have from 2.50 to 3.00, 6 students ranging from 3.0 – 3.59 and 14 students got more than 3.6. Total passed is 36.

The trend of GPA for the batch January 2021 is shown in the Table 7.

Table 7 GPA Progress

	BK	PK1	GK	INCO	Total
Sem 2021/2	40	1	0	0	42
Sem 2022/1	32	3	0	0	35
Sem 2022/2	35	2	0	0	37
Sem 2023/1	29	1	0	0	30
Sem 2023/2	42	0	0	0	42
Sem 2024/1	28	0	0	0	28

The progress of GPA is shown in Table 7, it can be seen that for the batch January 2021 [Sem 2021/2] out of total 42 students, 40 got BK,1 got PK1, 0 got GK and 0 doesn't complete the semester. In Sem 2022/1, 32 students come under BK and 3 come under PK1. In Sem 2022/2, 35 come under BK. In Sem 2023/1, 29 classified under BK. In Sem 2023/2, 42 falls under BK. In Sem 2024/1, 28 classified under BK.
Systematic comparison / analysis of the student data helps not only to identify and improve the strengths and weaknesses in the robotic program but also helps to close the gap between the program and IR 4.0. Overall, this helps to make informed decisions to enhance its quality and effectiveness.

4.3 Student Employment

The students after their graduation of IART degree program, majority of them were employed in various manufacturing and automation industries. Some they managed to get employment in multinational Industries, Oil refineries, food industries also in the areas of electrical and electronic companies. In the first batch, 50-80% of students were able to find employment within 4 months after completing their degree, whereas 30-50% of the students were employed from the second batch which graduated in January 2022. Students are also employed in middle east and African countries and as well as medium, large scale and small-scale industries. Amongst the companies that are attached with are Schneider electric, KUKA, Omron, Siemens, Intel, Proton, ABB, to name a few. From the time of the first batch graduation it is more than six months since this paper was presented. As stated above, although 80% of them have found employment within this period, the majority of graduates will find employment over time.

5. Impact of IR4.0 on Malaysia industrial growth

The implementation of bridging the gap between Industry 4.0 (IR 4.0) and the robotic and automation educational engineering program has significantly benefited a developing nation like Malaysia's industrial growth, mainly in the manufacturing sector. The benefits include enhanced productivity, increased innovation capacity, higher job creation, and improved resource utilization.

1. **Productivity and Efficiency**: The implementation of IR 4.0 technologies, such as robotics, automation, drones, AI, and IoT, has led to higher efficiency and productivity in manufacturing processes. By digitizing traditional manufacturing systems, companies can streamline operations, reduce costs, and increase output.
2. **Economic Impact**: The manufacturing sectors contribution to the Malaysian economy is significantly increased by the implementation of IR 4.0. It aims to increase the overall productivity per person by 30% by 2035, also the economic contribution from manufacturing sector also shown tremendous growth and improve Malaysia's ranking on the Global Innovation Index from 35 to within the top 30.
3. **High-Skilled Workforce**: In order to support advanced manufacturing technologies and to sustain economic growth a shift in enhancing the skills of the workforce is essential. This will result in increasing the high skilled workers from 19 to 36 % by 2025 in Malaysia.
4. **Innovation and Competitiveness**: The IR 4.0 improved digital infrastructure, accessible data, and funding support for research and development. Helped Malaysia to produce high quality products and services to remain on a global scale competitiveness.
5. **Support for SMEs**: SMEs improve their productivity and integrate into the high-tech manufacturing ecosystem with the support from Ministry of International Trade and Industry (MITI).

Overall, the strategic implementation of IR 4.0 is positioning Malaysia as a significant player in smart manufacturing and high-tech industries, driving economic growth and innovation across the country.

6. Conclusion

This paper has discussed the steps involved in bridging the gap between IR 4.0 and an Industrial automation and robotics undergraduate engineering program. It also gives the insight of curriculum development to narrow the gap by considering the feedback from the industry experts. To conclude the whole process significantly helped a developing nation like Malaysia to build their Robotic Road map to achieve economic growth and remain sustainable to meet the global challenges.

Acknowledgements

Our sincere appreciation goes to all the university faculty members involved and also all the Industry experts involved in Automation and Robotics Technology and IR 4.0 for their valuable guidance and encouragement.

References

1. Martin, F., Oberoi, P., Sargent, R., "The 6.270 RobotBuilder's Guide" , MIT Media Lab, Cambridge, MA,1992.
2. Turner, C., Ford, K., Dobbs, S., Suri, N., & Hayes, P., "Robots in the Classroom." In J. Stewman (Ed.),Proceedings of the Ninth Florida AI Research Symposium (pp. 497-500). Key West, FL:FLAIRS.
3. Turner, C., Ford, K., Hayes, P., Shamma, D., Manseur, R., "Robots in Education", Proceedings of the US-Japan Graduate Student Forum in Robotics, Osaka, Japan, November 1996.
4. W. Wolf and J. Madsen, "Embedded Systems Education for the Future," Proceeding of the IEEE, January 2000, pp.23-30.
5. A. McGettrick et al, "Computer Engineering Curriculum in the New Millennium," IEEE Transactions on Education,November 2003, pp. 456-462.
6. John J. Craig, "Introduction to Robotics, Mechanics and Control", 2nd Edition, Addison-Wesley. 1989
7. McKerrow, P. J., "Introduction to Robotics," Addison-Wesley, 1991
8. Sergeyev and Alaraje ., "Promoting Robotics Education: Curriculum and State-of-the-Art Robotics Laboratory Development'. The Technology Interface Journal/Spring 2010
9. Olga I. Vaganova, Zhanna V. Smirnova., "Development of training content for master students in course "mechatronics and robotics" at the University" .Amazonia Investiga. Volume 8, No 22
10. C. Li, L. Fu and L. Wang, "Innovate engineering education by using virtual laboratory platform based industrial robot " 2018 chinese's control and decision conference"
11. I Elamvazuthi Jeffery Law, Yedpal Singh, MKA Ahamed Khan, S Parasuraman, M Balaji, M Chandrasekaran "Development of autonomous tennis ball retriever robot education kit" 2015 Procedia computer science, volume 76, page 21-26, Elsevier.
12. W Faizura W Tarmizi, I Elamyazuthi, N Perumal, Ku Nuhanim, MKA Ahamed Khan, S Parasuraman, AV Nandedkar " A Particle Swarm Optimization-PID controller of a DC Servomotor for multi-fingered robot hand" 2016 2nd IEEE International Symposium on Robotics and Manufacturing Automation-IEEE Xplore page 1-6.

Authors Introduction

Dr. M. K. A. Ahamed Khan

He got his Power Electronics and Drives diploma from Germany, and a Diploma in Drives and Controls from Korea. He obtained his PhD in Robotics and Controls in the United States also his (PEng) USA and (CEng) in UK. He is a Senior member in IEEE also IEEE RAS Malaysia chapter past chairman. His area of research is robotics and controls. He has won many awards and published many papers in reputed journals and conference proceedings.

Dr. Mastaneh Mokayef

She obtained her PhD from UTM, Malaysia in the area of wireless communication. Currently attached to UCSI and works as an Assistant Professor in the Faculty of Engineering. Her key research focus is in the field of Antenna design and cellulur networks. She also holds Chartered Engineer (C.Eng.) from the U.K and Young Scientists Global distinguished Award from IEEE IAS.

Ts Amar Ridzuan Bin Abd Hamid
He is a lecturer in the faculty of Engineering at UCSI, Malaysia and holds his ME degree from UPM, Malaysia also a Diploma in post graduate studies from UCSI, University.

Mr. MHD Amen Summakieh

He obtained his M.Eng.Sc. degree from MMU Malaysia. His research interests include antennas design and cellular networks.

Dr. Sew Sun Tiang

She received her PhD in Electrical and Electronic Engineering from USM Malaysia. Her research areas are antenna design and communication networks and works as an Assistant professor at UCSI, Malaysia.

Dr. Wei Hong Lim

He received his PhD in Computational Intelligence from USM Malaysia. His areas of research are optimization and artificial intelligence. Currently he works as an Associate proessor at UCSI, Malaysia.

Mr. M. Suresh

He completed his two Post graduate degrees in Industrial Engineering and Power Electronics and Drives from Anna University, Chennai, India. He is a Life member in ISTE, India. Currently he is the Head of Electrical and Electronics Engineering Department, Murugappa Polytech College, Chennai, India. His research areas are Power electronics, robotics and drives. He has guided more than 50 students projects and published more than 10 research papers. He has teaching experience of more than 33 years.