THE ROADMAP TO INDUSTRIAL AUTOMATION AND ROBOTICS: THE SITUATION IN THE DEVELOPING ECONOMIES

Marvis I. Aririguzo
Federal Polytechnic Nekede,
Owerri
NIGERIA

Emmanuel C. Agbaraji
Federal Polytechnic Nekede,
Owerri
NIGERIA

ABSTRACT

This paper presents the roadmap to industrial automation and robotics: the situation in the developing economies. The complexity in today's industrial setup and the high need for accuracy and improved production quantity and quality brought about the significance of the study and implementation of industrial automation and robotics. The steps to implement robotic automation were presented. From the review it was observed that most developing economies are still recording very low results in the development and implementation of industrial automation and robotics while the developed economies are growing higher in this aspect. As a result, most developed nations are recording improved production quantity and quality while the reverse is the case in most developing nations.

Keywords: Roadmap, Industrial Automation, Robotics, Mechanization.

INTRODUCTION

The technology in using tools to support man to do work, improve job performance, achieve better results or complete greater amount of work in less time frame can be traced back to our forefathers of the ancient generations past. Technology is like a dynamic process which keeps evolving to improved stages as the generations pass by, and which should be adopted generally and globally to meet up with the higher demands for the technological products by the rising population of humans in every nation. For instance, technology behind the manual labor, using hoes which can take a good number of well-fed men some days to complete a farm work grew to mechanization with which only one person can use a tractor to complete the same size of farm in few hours. Subsequently, the dynamism of technology has evolved into a new stage known as automation which gives autonomy to some tools making them capable of standing alone and do some predefined jobs without direct human intervention. Industrial automation is concerned with the use of mechanical, electrical, electronic and computer based systems in the operation and control of production. The history of industrial automation is characterized by periods of rapid change in popular methods. Either as a cause or, perhaps, an effect, such periods of change in automation techniques seem closely tied to world economics (John, 2005).

Automation using robotics is one of the latest trends in technology, which has the potential to improve the productivity of manufacturing. Robotics involves the design, construction and implementation of machines to perform tasks traditionally conducted by humans, manufacturing processes benefit most from improved flexibility (Laurent et al, 2013). A robot is an electromechanical which is guided by computer or microcontroller and electronic programming. Robots are flexible in that they can easily change their function in order to meet the demands of the manufacturer or the client. In doing so, robots essentially perform three tasks, as they "sense" by drawing on environmental stimuli, then "think" by using pre-set algorithms for planning and finally "act", using the robots' end-effector (e.g. a clamp or welding torch) to pick up and place an object or weld two objects together (Laurent et al, 2013). Today, robotics affect positively a broad sector of economic activities from automotive and electronics industries to food, recycling, logistics, etc. (Arantxa et al, 2005). In recent records Europe, USA, some Asian countries such as Japan, Korea, and China etc have advanced greatly in the adoption of industrial automation using robots which can be attributed to their efforts in the technological contributions towards the development of robots and the full involvement of the government and the private industries in the adoption processes of the technology. However, in spite of the recent economic growth recorded by these above mentioned countries as a result of their full adoption of industrial automation, adoption of robots in industrial automation is still constrained in most developing nations. These constraints can be attributed to the following factors: negligence of the public sector (government) towards career development in the field of automation and robotics, lack of industrial partnership with academic excellence in the areas of research and funding and lack of government support to the start-ups whose innovative abilities towards mechanization and automation have been quashed by insensitive politically inclined roles played by the government officials.

Countering these obstacles are a number of trend drivers, including federal government full and strictly monitored support for advanced research and development activities in the fields of industrial automation and robotics, which have led to the emergence of several clusters of excellence in the field. Secondly, industrial partners should support academic excellence in these two fields by providing researchers with funding and a channel for market entry as a strict policy which should be created by the government. Furthermore, the public sector should support start-ups in bring their innovative measurement technologies and robotics solutions to market. Lastly, the private and public sectors, and tertiary institutions in the developing nations should embark on research and commercial projects to study and produce automated machines for local manufacturing processes such as palm oil processing using robot which can pound, press out oil, and store oil in a container.

To enhance its role in promoting the uptake of measurement technologies and robotics, the public sector should explore three strategic avenues. First of all, policy makers should assess how the public sector can best assist innovative businesses in bringing their measurement technologies and robotics solutions to market. Secondly, the public sector ought to investigate how it can use awareness raising activities to catalyse the market for measurement technologies and robotics solutions. Finally, the public sector could explore what support schemes innovative start-ups need, for instance, in areas related to business plan development or intellectual property.

LITERATURE REVIEW

According to Laurent et al (2013) automation is the use of machines, control systems and IT solutions to improve the productivity of an industrial process that would otherwise be done manually. It should not be confused with mechanization, which comprises mechanical solutions operated by workers as part of the manufacturing process. Where automation differs from mechanization is that automation removes the need for workers to operate the machinery while increasing load capacity, speed, and repeatability. He continued that today, automation and process integration in manufacturing is continuously improving as a result of technological developments. The key milestones in automation until now are listed in Table 1.

Table 1: The key milestones of automation (Kalpakjian , 2008)

Date	Development
1920-1940	Transfer machine; mass production
1940	First electronic computing machine
1943	First digital electronic computer
1947	Invention of the transistor
1952	First prototype numerical control machine tool.
1954	Development of the symbolic language APT (Automatically Programmed Tool); adaptive control.
1957	Commercially available NC machine tools.
1960	Industrial robots
1965	Large-scale integrated circuits
1968	Programmable logic controllers
1970s	First integrated manufacturing system; spot welding of automobile bodies with robots; microprocessors; minicomputer-controlled robot; flexible manufacturing system; group technology.

Industrial robots can be described as advanced automation systems that utilize programmed computers as integral part of their control. They run production lines and control stand-alone manufacturing systems, such as various machine tools, welders, inspection systems and laser-beam cutters. Even more sophisticated are the new robots that perform various operations in industrial plants and participate in full automation of factories. According to the International Federation of Robots (IFR), an industrial robot is defined as "an automatically controlled, repro-grammable, multipurpose manipulator programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications".

Robots have mostly been used since they were first invented over the last 50 years in industrial manufacturing (Forge and Blackman, 2010). However, according to International Federation of Robotics statistics (IFRS), despite promises of an industrial revolution as a result of the emergence of this technology, the best known uses of robotics in manufacturing is in the automotive industry. These industrial robots are for the most part programmed to carry out specific repetitive actions with little variation, but with a high degree of precision and accuracy.

Lauri (1992) suggested that there must be wide-ranging changes in construction before automation can be implemented in practice; this is also applicable in all the fields where automation can be implemented in practice. Therefore, the processes involved in the flow of work must be analyzed and improved before automation can be implemented in that area.

The Journey so Far

The Federal University of Technology (FUT), Minna identified non-inclusion of foundational mechatronics subjects in the educational curriculum at all levels as one of the challenges facing innovative and creative thinking among Nigerians. This, according to the university, is evident in the fact that almost every task is done manually within the country. It believes system automation is an integral part of the development of any nation. In a bid to bridge this gap, the university created a new School (faculty) of Information and Communication Technology (SICT). Presently, the university is organizing a maiden edition of Nigeria Robotics Championship (NIROC), which is aimed at introducing innovation and creativity in artificial intelligence, mechatronics engineering, and robotics, all of which drive automation, to all spheres of life in Nigeria (Vanguard, 2013).

Edweekng (2013) reported that Interest in robotics is flourishing in Africa. Four (4) African countries: Egypt, Ghana, Nigeria and South Africa participated in the World Robot Olympiad (WRO) 2012, hosted by the Ministry of Education Malaysia in Kuala Lumpur, Malaysia. The Century Group in collaboration with Arc Lights Limited sponsored the winners of MINDSTORMS Nigeria – National Robotics Competition to represent Nigeria at the annual World Robotics Olympiad. According to the news (Edweekng, 2013) since the study of robotics cuts across several disciplines, such as applied ICT, science, technology, engineering and mathematics, this makes it a popular and effective teaching tool for introducing students to the science, technology and mathematics curricula. And this is also what makes robotics an ideal career choice. Encompassing multiple industries and multiple skills, robotics is definitely not a monolithic field with a single career path. Robotics, today, is a major growth segment in industry and there is a marked increasing demand for young and talented robotics professional to work in the industry (Edweekng, 2013). However, the current situation in most developing economies is almost the reverse of that in the developed ones in the area of industrial automation and robotics. There has been a clear record of poor technological development and deployment in most developing nations which may contribute to the poor production level in those nations.

THE ROADMAP

Generally, no nation can develop beyond her technology or experience in economic boom on borrowed technology without investing in developing it indigenously. Engaging in human capacity building through establishment and funding of research and training centers on embedded systems, computing and programming, electronics and control, machine design and development will provide the platform for indigenous solutions in the form of equipments, machines, tools, products, etc ranging from very simple to complex systems to be developed so as to meet the growing needs of our agricultural, manufacturing and other industrial sectors. An embedded system is a micro-processor based system that is built to control a function or range of functions and is not designed to be used by the user in the same way that a personal computer (PC) is and it has become the vital component to achieve industrial automation and robots. Embedded digital technology is present in all equipments and systems used to achieve intelligence in robots over the former stage of technology which is mechanization. Fortunately, the embedded systems are presently very cheap in the market and can be studied and programmed with user manuals. Figure 1 shows the growth trend of robots from manual form or stage of the technology.

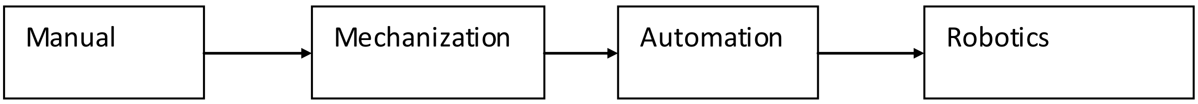

Figure1: Growth trend of robot technology

Mechanization refers to the replacement of human power with mechanical or manual power of some form. The use of hand power tools (which is the manual operation) is not an example of mechanization. Automation and mechanization are often confused with each other; Mechanization saves the use of human muscles whereas automation saves the use of human judgment. Mechanization displaces physical or manual labor, whereas Automation displaces mental labor as well as manual labor. Automation is the replacement of human thinking with computers and machines and creates jobs for skilled workers at the cost of unskilled and semi skilled workers. It affects many industries at the same time (Sumtech, 2013).

The fields of automation and robotics are often confused; their differences are revealed through how each works. One of the major differences between automation and robotics is whether the machine performs a single set of operations or if the sequence can be mixed up or changed for better efficiency. If the machine receives sensory feedback, then the machine can change sequences automatically for the best results. Some machines are able to learn from mistakes, or through constant exposure, while others will lack this ability. The level of movement also is different between automation and robotics, with one being faster and more complex (Wisegeek, 2016). Some of the distinguishing factors are presented as follows (Iasreview, 2012):

Set operations and Sequence: Automation can only follow one set of operations, and it cannot be changed once programmed. Robots are made to perform several jobs at once, and the sequence of operations can be switched around to make the processes more efficient. The timing of the operations also can be changed in robotics, if needed.
Outside stimuli: The automated machine will not react; even if there is an object blocking the automation, it will continue doing the same operation. Robots are made to react so, if something blocks or stops the robot, it will change operations to best fit the situation.
Artificial intelligence (AI): Automated machines are unable to collect knowledge and can't be programmed with any form of intelligence. Robots can be made with intelligence and they are able to learn from mistakes; this allows the robot to fix problems, if it is exposed to them long enough.
Level of movement: The amount of movement and overall velocity of both a robot and automation are generally very different. Automated machines are made for slow work and are typically programmed with very simple movements. For example, an automated arm may be able to pick up a chip, rotate and then place the chip somewhere else. A robot can work faster and is able to accommodate complex movements.

Steps to Implement Robotics Automation

The following steps were presented by HGS (Hinduja Global Solutions) for robotic automation program implementation.

1. **Identify opportunities to automate.** It is essential to determine process adaptability to automation. Each unique process is more open/ viable to automation or not based on various factors such as process size, industry, and current process.
2. **Validate the opportunity.** Check how adaptable the process is to being automated. If we look at most processes, we notice that they typically comprise both transaction and decisioning parts. Automation can be designed to achieve some quick wins on the transactional part which is the more time-consuming repetitive task.
3. **Select a design model.** Select the best model for your requirement. You may need to redesign the process to maximize the scope for automation. In some cases, this yields additional benefits. Design the automation plan that suits the business structure. Customize the automation model to suit the process needs.
4. **Develop the automation plan.** Conduct a thorough study of the process and understand all the "exception" scenarios. Automate time-consuming repetitive tasks in processes that include these. Develop the automation implementation plan in phases, considering all of the level 3 scenarios. Instead of automating all scenarios, automate

about 75% and have experts handling the rest of the scenarios. Evaluate plan performance at every phase and move to the next phase.

5. **Deploy the pilot phase.** When you develop an automation plan and are ready to implement it, run a pilot project first. This allows you to observe the effectiveness and overall performance of your automation plan with an actual process in real-time. Take the results of the pilot project and make improvements accordingly. Look at the results of the pilot and then include those scenarios that need to be automated and those that can remain an exception.
6. **Roll out the plan.** Besides development of automation, build a plan needs for training and handling contingency depending on the criticality of the process. It is good to ensure that while people are trained on the revised process there is also documentation on the process before automation to handle any contingency due to a change in applications or systems.
7. **Maintain your automation activity.** Automation is not always a one-time activity, and it is not something to be executed and then forgotten. There will be changes in the process and systems, and there should be a good change management process to handle any changes. Estimate the impact of change in systems or process and have a plan ready for this. At this last phase, prepare a change management plan.

INDUSTRIAL AUTOMATION AND ROBOTICS APPLICATIONS

Industrial automation and Robotics can be deployed in numerous types of work in our present society which ranges from construction, manufacturing, research, transportation, Medical, Human support, security and entertainment and many more. Figure 2 shows the estimated operational stock of industrial robots 2011-2012 and forecast for 2013-2016. Most developed countries such as Japan, USA, China, Germany etc are recording high level of dependence on industrial automation and robotics for improved production/manufacturing, construction etc. Some of the top popular applications of industrial robots are as follows:

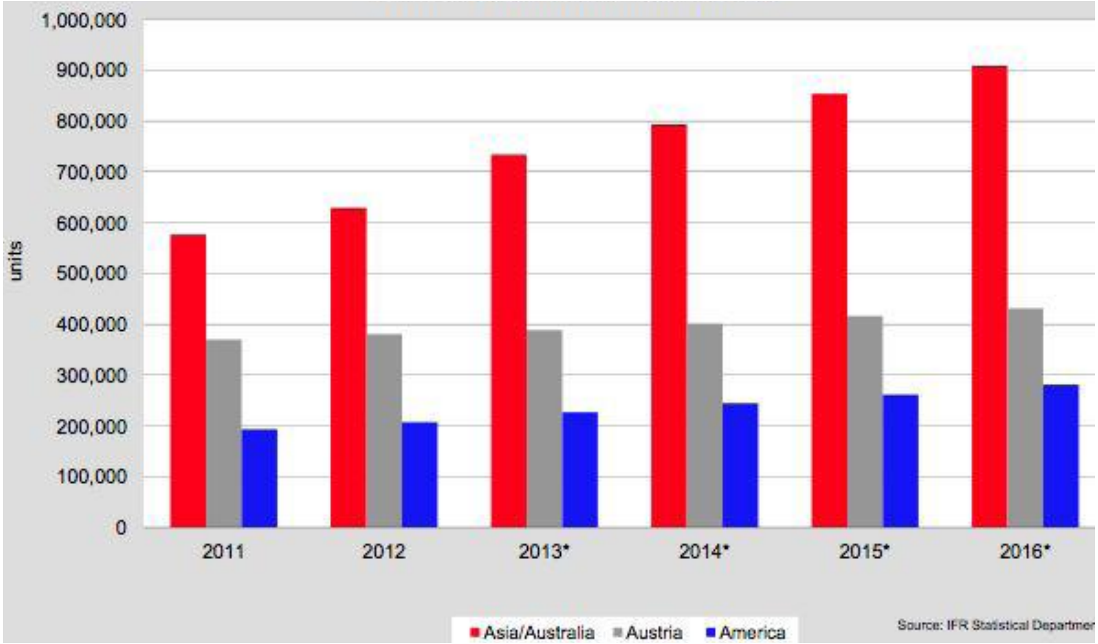

Figure 2: Estimated operational stock of industrial robots 2011-2012 and forecast for 2013-2016

Robotic Material Handling: Material handling (figure 3) is the most popular application with about 38% of operational stock of industrial robots worldwide. This includes robotic machine tending, palatalizing and various operations for metal machining and plastic moulding. With the introduction of collaborative robots in the last few years, this part of the market is always increasing (Jobin, 2014).

Figure 3: Robot handling materials (Jobin, 2014)

Robotic Welding: This segment mostly includes spot welding and arc welding which is mainly used by the automotive industry. Spot welding is still more popular than robotic arc welding but not for long; as arc welding is becoming very popular in the metal industry. More small workshops are beginning to introduce welding robot into their production. In fact, with the price of robot going down and the various tool now available on the market; it has become easier to automate a welding process.

Construction Industries: Application of robots in the construction industry for performing various tasks is growing. Basic activities in building construction, and civil engineering projects developed by robots are: positioning, connecting, attaching, finishing, coating, concreting, building, inlaying, covering, jointing, scaffolding, demolishing, tunneling, inspecting, and repairing elements (Warzawaski, 1990). Japanese construction companies are research leaders in the development and application of robots in their construction projects. In the United States, there is a growing interest in the academic circles, research institutions, and construction companies for the development of construction robots.

Assembling Operations: Assembly operations include: fixing press-fitting, inserting, disassembling etc. This category of robotic applications seems to have decreased over the last few years, even while other robotic applications have increased. The reason why the applications are diversified is because of the introduction of different technologies such as force torque sensors and tactile sensors that gives more sensations to the robot.

Robot Dispensing Operations: These include painting, gluing, applying adhesive sealing, spraying, filling, etc. Robots make repeatable and accurate process and this helps to realize the smoothest dispensing job.

Processing: Processing is not a big segment of industrial robots and this is probably because a lot of automated machines are available on the market to do specifically these applications. The main application areas are mechanical, laser and water jet cutting.

Nuclear Reactor Cleanup: In 2011, three out of the six nuclear reactors melted down at a nuclear plant in Fukushima, Japan. Naturally, the environment was not suitable for humans to clean up and access the damage, so a fleet of robots was assembled to help their human operators. The PackBot, by iRobot, was one of the first robots to arrive on the scene. This robot is designed to be modular, and can be quickly configured based on mission needs. It's able to climb stairs, as well as transmit audio, video, and sensor data to an operator (Cook, 2014).

Underwater/Marine Operation: Deployment of robots mostly remotely operated robots in the underwater operations is increasingly becoming popular due to the risks or danger involved in sending human workers in some dangerous ocean depths. Remotely operated vehicles are becoming popular especially in the oil exploration works.

Advantages of Industrial Automation and Robots

The robots can perform the tasks which the humans find them dangerous, boring or difficult. They can do the work with constant speed and precision and they continue and finish the work without feeling sick. Other advantages presented by robots are as follows (Skibniewski, 1988): a) improvement in work quality, b) reduction of labor costs, c) savings accrued on safety and health improvements, d) time savings, and e) improvement in productivity.

Disadvantages of Robotics Automation

Soffar (2015) presented some disadvantages of robot in mostly the industries:

1. The industries prefer utilizing the robots than the human workers. Hence, the unemployment rate will increase, and many people who cannot get work will become poorer while the company owners will get richer.
2. The companies should calculate the cost of the robotic automation in light business, It sometimes costs a lot of money greater than the financial budget and they need regular maintenance which costs a lot of money.
3. The robots can work in the factory with limitations. The human do the tasks that require creativity, decision-making, adaptation and job learning.
4. If the employees have no experience to deal with the robots, they will need training program to interact with the new robotic equipment and it will take time and cost a lot of money in the financial output.
5. The robots can protect the human workers from some hazards. The robots can create other safety problems and they can cause new dangers which must be taken in consideration.
6. The companies must plan before using the industrial robots as using the robots without planning in the factories does not guarantee the results, so the companies will have the difficulty to achieve their goals.

CONCLUSIONS

The roadmap of industrial automation and robotics must involve the knowledge of the trend of technological development from the manual or mechanical power tools methods through the mechanized methods to automation and finally robotics. There is a huge rise in the automation and robotics development and usage recorded in most developed economies but the opposite is the case in most developing economies. Industrial automation and robotics have many applications and advantages in today's industrial activities which have contributed greatly in development of most national economies. It was concluded that automation and robotics technologies should be studied and applied to indigenous processes for improved production quality and quantity.

REFERENCES

Alantxa R.B., et al, (2005). Industrial Robot Automation, White Paper Report of the European Robotics Network.

Cook J. (2014). 10 Industrial Robot Applications, Available from: http://www.eetimes.com/document.asp?doc_id=1324004

Edweekng (2013). Nigerian Students Rank Best African Team in Junior High – Regular Category at the World Robot Olympiad 2012, Malaysia. http://edweekng.com.ng/edweekng/index.php?option=com_content&view=article&id=107:nigerian-students-rank-best-african-team-in-junior-high--regular-category-at-the-world-robot-olympiad-2012-malaysia&catid=3:pre-tertiary&Itemid=54

Forge, S. and Blackman, C. (2010). A Helping Hand for Europe; the competitive outlook for the EU robotics industry. JRC: Institute for Prospective Technological Studies.

Iasreview (2012). Difference between Automation and Robotics, Available from: http://iasreview.blogspot.com.ng/2012/12/difference-between-automation-and.html

International Federation of Robotics definition of an industrial robot. Available from: http://www.ifr.org/industrial-robots/

International Federation of Robotics statistics. Available from: http://www.ifr.org/industrial-robots/statistics/

Jobin J. P. (2014). Industrial Robots: 5 Most Popular Applications, Available from: http://blog.robotiq.com/bid/52886/Industrial-robots-5-most-popular-applications

John J.C., (2005). Introduction to Robotics Mechanics and Control, Pearson Educational Inc, USA, 3rd Ed. Pg 1

Kalpakjan S. (2008). Manufacturing Processes for Engineering Materials. 5th ed.

Laurent P., (2013). Advanced Manufacturing Measurement Technologies and Robotics, Business Innovation Observatory Contract No 190/PP/ENT/CIP/12/C/N03C01

Lauri K., (1992). Process Improvement and Automation in Construction: Opposing or Complementing Approaches? The 9th International Symposium on Automation and Robotics in Construction June 3-5, 1992 Tokyo, Japan

Skibniewski M.J. (1988). Robotics in Civil Engineering, Van Nostrand Reinhold Company, New York, pp.5, pp.8, pp.10.

Soffar H. (2015). The advantages and disadvantages of robots in the factories, Available from: http://www.online-sciences.com/technology/the-advantages-and-disadvantages-of-robots-in-the-factories/

Sumetech, (2013). Differentiate between Mechanization and Automation, Available from: https://somemmec.wordpress.com/2013/03/09/differentiate-between-automation-and-mechanization/

Vanguard, (2013). Why Nigeria Lag Behind in System Automation – FUT Mina http://www.vanguardngr.com/2013/09/why-nigeria-lags-behind-in-system-automation-fut-minna/#sthash.M7wzjob4.dpuf

Warzawaski, A. (1990). Industrialization and Robotics in Building: A Managerial Approach, Harper & Row, Inc.; New York, pp.369-373, pp. 401-418.

Wisegeek (2016). What are the differences between Automation and Robotics, Available from: http://www.wisegeek.com/what-are-the-differences-between-automation-and-robotics.htm