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Robotics Innovation in Kenya as an Opportunity for Industrial Growth: Challenges and Prospects for TVET Institutions and Universities

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Abstract:
Advances in science and technology in the world today have led to major innovations to overcome the challenges experienced by various economies in the quest for economic growth and development. Several countries have embarked on multibillion projects and educational programs in order to equip their citizens with relevant skills to enhance development. The field of robotics has commanded a lot of attention in the current decade and is considered one of the breakthroughs that is currently revolutionizing the world. Many tasks that were performed by human beings before are now performed by autonomous mechanical machines controlled by programs embedded in small microchips. In Kenya, the field of robotics has currently drawn a lot of interest since the inception of robotic competitions in 2010 among TVET institutions and universities at regional and national level. Students under the guidance of lecturers have always embarked on the design of autonomous robots to meet set out design standards and guidelines in order to execute designated tasks during competition. Being a new area of innovation, institutions and design teams have been faced with major challenges in this endeavor. This paper reviews challenges experienced by TVET institutions and design teams and gives insights and recommendations on how to curb this challenges.

Keywords*: Robotic & Robots, TVET institutions, Automation*

1. Introduction

The robotics industry has seen magnificent growth worldwide in early 21st century (Shukla & Shukla, 2012). The term 'robot' came from Czech and means 'forced labor'. This term in its present interpretation was invented by Czech writer Karel Capek in 1921. The concept of an industrial robot was first patented in 1954 by G. C. Devol (U.S. patent number 2988237). The first industrial robot was developed by George Devol and Joseph Engelberger in 1959. It weighed two tons and was controlled by a program on a magnetic drum. They used hydraulic Actuators. The first industrial robot was installed by Unimation Inc. in 1961 (Koren, 1985). The first digitally operated and programmable robot, the Unimate, was installed at General Motors on a production line. Since then thousands of robots have been installed in industry in the United States, Japan and Europe. The first National Symposium on Industrial Robots was held in 1970 in Chicago, USA. A year later it was upgraded to an international conference and was called the International Symposium on Industrial Robots (ISIR). The purpose of this symposium was to provide researchers and engineers worldwide an opportunity to present their work and to share their ideas in the fields of robotics. In 1997 the symposium changed its name to International Symposium on Robotics (ISR) and included the technology of service robots. Today the ISR still represents a meeting point for all scientific, technical and industrial topics related to robotics. One main goal is to bring academia and industry together. The symposium is organized annually by a national robot association either in America, Europe or Asia in conjunction with an international robot exhibition (IFR, 2012).

The world around us is changing at unprecedented and unimaginable speed which is giving way to greater explorations in Robotics Industry. The robotics industry includes vast range of industrial robots and service robots. As defined by ISO 8373, the industrial robot is 'an automatically controlled, reprogrammable, multipurpose manipulator programmable in three or more axes, which may be either fixed in place or mobile for use in industrial automation applications.' According to the International Federation of Robotics, a service robot is 'a robot which operates semi or fully autonomously to perform services useful to the well being of humans and equipment, excluding manufacturing operations'. The early age of 21st century sees that both types of robots are capturing the market rapidly to fill the emptiness in our society world-wide.

Industrial robots have now revolutionized industry. These robots do not look or behave like human beings but they do the work of humans. Robots are particularly useful in a wide variety of industrial application, such as material handling, painting, welding, inspection and assembly. Robots are bringing in a new perspective of the factory of the future that will be unmanned yet fully operational. Current research efforts are focusing on creating a 'smart' robot that can 'see', 'hear', 'touch' and make decisions (Koren, 1985)

It is obvious that there are high expectations as to the future potential of robotics, even euphoric ones and somewhat unrealistically utopic (Moravec, 1988). On the other side, there are sceptical views, seeing robotics as one of the most powerful technologies of the 21st century, together with genetic engineering and nanotechnology (Joy, 2000), threatening to
make humans an endangered species. A more moderate and realistic, but still fascinating approach has been taken by a study group, consisting of experts from engineering, medical, philosophical and legal sciences, discussing the provoking question whether humans could be substituted by robots (Christaller et al., 2001). All this are anticipations and agitations by different groups about the future of robotics. Even so, there are different forces that motivate different economies in the world to embrace robotics.
According to Gorle, P. & Clive, A. (2013) there are three driving forces for using robotics as follows:

- Where the product cannot be made to satisfactory precision, consistency and cost, without Robotics.
- Where the conditions under which the current work is done are unsatisfactory (may be illegal in the developed countries), but where a robot will operate.
- Where (particularly) a developed country manufacturing unit with high labour costs is threatened by a unit in a low labour cost area.

Use of robots in modern industries is on the rise throughout the world especially in the manufacturing sectors. Although this is true there are still arguments against robots, contested by the suppliers, in that they are less flexible in operation and demand more up-front investment than the employment of low cost labour often rendered by immigrant in the developed countries. Some countries like China and Brazil have a low indigenous labour. The high labour cost sectors are therefore often more likely to use robots.

2. The Need For Robotics In Developing Countries

According to Gorle, P. & Clive, A. (2013) Pressure to use robotics in the developing countries has been that, despite availability of low cost labour, consistency and accuracy required to compete with or meet the requirements of the developed markets, can sometimes only be achieved by robotics. Developing countries should also reduce dependence on high cost labour by introducing automation when it offers an economical alternative.
Five other economic factors have to be considered:

- Globalisation
- Increasing speed of technology development
- Age and skills profiles
- Wage levels
- Health and safety legislation levels

The International Labour Organization (ILO) estimated that, globally, about 2.2 million people die every year from occupational accidents and diseases, while some 270 million suffer serious non -fatal injuries and another 160 million fall ill for shorter or longer periods from work-related causes. This represents an enormous toll of suffering for workers and their families. Furthermore, the ILO estimated that the total costs of such accidents and ill health amount to approximately 4% of the world's GDP. Other organisations have estimated that about 5% of the burden of diseases and injury in established market economies can be attributed to work, which agrees with the ILO's figure. It is also worth mentioning a recent study by the European Commission which estimates that the costs of occupational accidents in the EU15 (15 European Union Member States) in the year 2000 was €55 billion a year (ILO, 2006). The need for robots to replace human labor especially in risk areas can therefore not be overemphasized. The demand for products is also overwhelming the few production lines in factories and hence automation is the only way to go in order to increase production.

2.1. Robotics Global Trends

There is a general shift in industrial operations in the world today and many manufacturing industries have embraced robotics in their production. According to International Federation of Robotics (2014) statistics shown in figure 1, the number of industrial robots has been on the rise except for 2012 when there was a slight drop of 4% due to decline of robot sales to the electrical electronics industry. Based on the results of the International Federation of Robotics (IFR) quarterly statistics, the IFR estimates that in 2013 about 168,000 industrial robots were sold, 5% more than in 2012 (World Robotics, 2013).

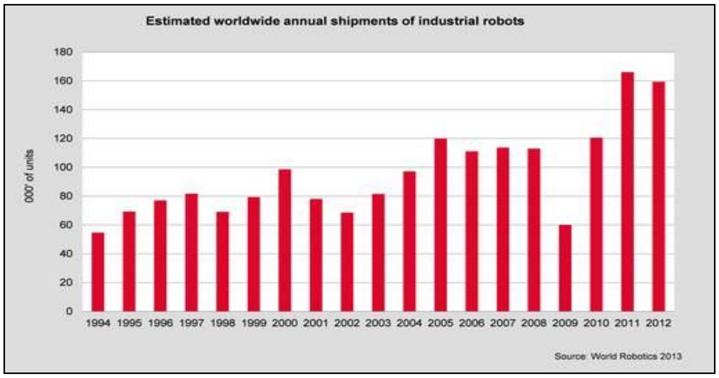

Figure 1: Estimated worldwide shipment of industrial robots.

The trend portrays a rapid rise in application of industrial robots over the years and hence sends a message for developing economies to urgently embrace robotics in order to brace themselves for future automation in the industrial sector. About 70% of the total robot sales in 2012 went to Japan, China, the United States, Korea and Germany. Figure 2 shows the estimated operational stock of multipurpose industrial robots at year end in selected countries.

Country	2011	2012	2013*	2016*
America	**192,966**	**207,017**	**226,550**	**281,000**
Brazil	6,971	7,576	9,170	17,400
North America (Canada, Mexico, USA)	184,679	197,962	215,650	260,800
Other America	1,316	1,479	1,730	2,800
Asia/Australia	**576,545**	**628,889**	**733,500**	**908,500**
China	74,317	96,924	121,200	215,800
India	6,352	7,840	9,300	16,300
Japan	307,201	310,508	309,400	312,900
Republic of Korea	124,190	138,883	155,300	201,700
Taiwan	29,837	32,455	35,800	43,000
Thailand	13,088	17,116	20,600	32,600
other Asia/Australia	21,560	25,163	81,900	86,200
Europe	**369,965**	**380,546**	**388,800**	**431,700**
Czech Rep.	5,890	6,830	7,800	11,000
France	34,461	33,624	33,000	33,200
Germany	157,241	161,988	165,800	177,900
Italy	62,245	60,750	58,600	55,400
Spain	29,847	28,911	27,300	27,100
United Kingdom	13,641	15,046	15,500	20,000
other Europe	66,640	73,397	80,800	107,100
Africa	**2,495**	**2,858**	**3,300**	**4,900**
not specified by countries**	11,126	16,079	20,850	33,400
Total	**1,153,097**	**1,235,389**	**1,373,000**	**1,659,500**

Sources: IFR, national robot associations.
*forecast
** reported and estimated sales which could not be specified by countries

Figure 2: Number of units of estimated operational stock of multipurpose industrial robots at year-end in selected countries

It is estimated that Africa was to have about 3,300 industrial robots by end of 2013 out of 1,373,000. This is only 0.24% industrial robots in Africa. It's an issue of great concern that Africa procures the smallest number of robots among all continents and hence an indicator that Africa is lagging behind in industrial automation. While jobs are changing, the educational attainments in Africa seem to be lagging. This therefore poses a great challenge for developing countries to urgently embrace robotics in order to develop capacity to handle robots in the industrial sector since the world is heading in this direction.
Figure 3 shows the annual supply of robots to various industries between the year 2010 and 2012.

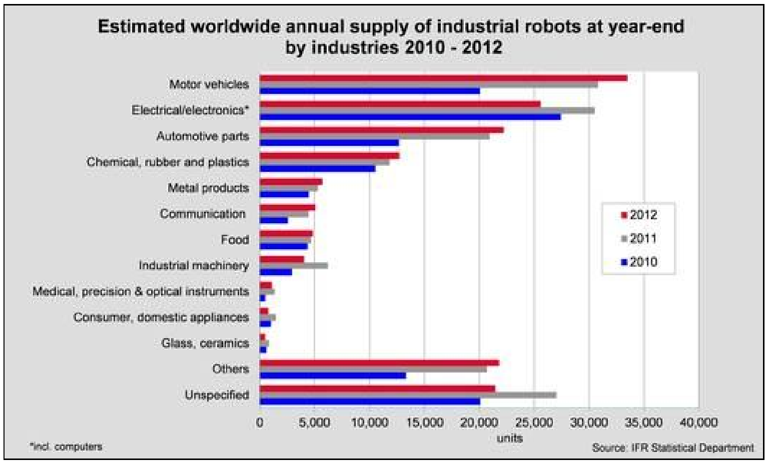

Figure 3: Annual supply of industrial robots between 2010 to 2012.

The motor vehicle industry, electrical and electronics industry and automotive parts industries seem to be procuring the largest number of industrial robots. This again calls for inclusion of more robotics and automation courses to students allied to the mechanical, automotive and electrical engineering trades in universities and TVET institutions in developing countries and Kenya in particular. According to IFR (2013), the average robot density in the world was about 58 robots per 10,000 employees in 2012.

3. Robot Innovation Competitions

There are many robot competition contests around the globe. This has helped learners to recognize the importance of the field of robotics and even exploit their potential without which they wouldn't have realized. Among the famous robotics competitions is the National Robotics Challenge competition in the United States which began in 1986, ABU Asia-Pacific robot contest 'Robocon' has been in place for a long time.

According to Amigoni et. al. (2013) competitions are a widely used and successful tool to promote scientific and technological progress in robotics. However, their usefulness for scientific research and for successful transfer of robotic technology from laboratories to industry may be increased by introducing a scientific approach to their design, and by structuring them as benchmarking competitions. Competitions can be designed such that the tests faced by robots can be considered as scientific experiments. Solving real industrial challenges and objectives should be knit into the robotics competitions if this innovation has to achieve the desired end.

Six robot contests have been held in Kenya since the inception of robotics by members of JICA in collaboration with the then Ministry of Higher Education, Science and Technology. Robotics is a wide area that can offer self employment to the youth in the local industries as it exposes them to both scientific and practical skills that can help them to come up with effective machines. This is an area of great potential for Kenya as a country for use in alleviating poverty and unemployment.

4. Challenges Of Robot Innovation Design

The design and construction of robots has been the first and greatest major challenge of many competing teams not only in Kenya but also to the rest of the world. According to Billard (2005), matching the body and brain of the robot and the aesthetics of the robot body have been the major challenge of robot design in Switzerland Robota mini-humanoid robot construction project. He points out that for the 8 years the crucial constraints when designing Robota's body have been cuteness, human-likeness and naturalness of the motions. People are more likely to interact with attractive faces than unattractive faces. Its therefore paramount that the robot be as attractive as possible.

Several challenges have been experienced by TVET institutions and Universities in Kenya during their robot construction in readiness for competition during regional and national science, technology and innovation exhibitions. The challenges range from administrative, design and on stage during demonstration as discussed.

4.1. Administrative Challenges

- Procurement process and procedure takes a longer time which involves identification of at least three suppliers and several other stages. This consumes time that may have been used to design and test and re-evaluate the performance of the robot. If this can be done early, developers will have enough time to concentrate on the actual development and testing of the robot to perfection.
- Robotics being a new concept to be incorporated in TVET institutions means that there were no ready suppliers for robot parts hence getting parts in the market is an uphill task. There are very few supplies of the robotics parts in the country. In fact some of the few suppliers first get quotations from the institutions for this parts then order for abroad. Time is a factor here and this further complicates the design of the robots because until such components are availed no designing can take off.
- Lack of the robotic components within the immediate geographical areas of the TVET institution and in Kenya generally due to limited number of suppliers has seen the cost of the robotic components soar to unimaginable heights. The cost of building one robot is approximately 1 million. Asking for such kind of money from the TVET institutions would not be

easy given the status of most of the TVET institutions in Kenya. Institutions would rather invest it in stocking the libraries or other aspects than investing in robotic research. This has led to some TVET institutions and Universities not taking part in this innovation.

4.2. Technical Challenges

- Many institutions have had a challenge of the robot's cognitive capabilities matching its physical appearance. The physical dimensions and tasks to be executed have often time not matched hence robots fail to perform designed tasks. The dimensioning of the robot parts greatly affects its performance.
- Aesthetics of the body of the robot has made some robots seem shapeless and not easy to comprehend. Neatness has been compromised most of the time. Dimensioning of the robot needs foresight and experience in robot construction which are skills still under development in the institutions.
- Design of the mechanical and electronic systems of the robot has been a great challenge to the robot teams. The arm and gripper mechanism has been a heartache venture for most institutions yet this is among the most important part of the robot design if it has to be able to execute tasks assigned.
- Programming of the robot has also been a challenge due to low knowledge of the software used in programming although this has improved over time. Rarely have the robots successfully completed a task given since the programming has been deficient.

4.3. Challenges During Competition

- Failure to perform given task or. Many factors have been attributed to contribute to this but the most critical is the change of operating environment of the robot in terms of lighting and other parameters like movement surface.
- Malfunction of robots after start of game. This has mostly been due to power failure and component failure due to mechanical incompatibilities and at times shorting of electrical components and loose electrical connections.

Majority of the robots from a number of institutions did not move because of lack of some components or were incomplete. This was attributed by the fact that most of the robotic parts are very expensive and hence could not be purchased or did not arrive in good time.

5. Prospects And Recommendations For Robotics In Kenya

- Stronger collaboration between industry and robotics science research institutions like universities and TVET institutions should be set up and enhanced in order to create local competitive robotics human resource. This can be done by industries posing real challenges they face from day to day and fund research institutions to come up with local solutions to their problems.
- The Kenya Institute of Curriculum Development should consider including aspects of industrial automation and robotics in all levels of the curriculum and especially engineering trades in order to sensitize learners on current trends in the industrial sector and make graduates globally competitive.
- Robotics competitions in Kenya should be expanded to include primary schools and secondary schools in order to inculcate innovative culture to the students at an early age in life.
- The NCST should seek for avenues of getting more the private sector participants by coming up with a collaboration platform between robotics research in TVET and higher education and industry. This may see industry being willing to fund research that is of mutual benefit to both institutions and also raise the confidence of the private sector on educational institutions.
- The NCST should mobilize institutions at regional levels to pool resources and facilitate robotics training from time to time in order to build capacity for the future of robotics.
- Institutions should develop appropriate motivation mechanisms like reward schemes to encourage the robot teams to devote more time in research to come up with fully functional robots. The administrations of institutions should also be supportive to the teams in all ways.

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