Robotics and Artificial Intelligence in Africa

By David Vernon

Artificial intelligence (AI) provides many opportunities for social and economic empowerment in developing countries. However, when one thinks of Africa, robotics does not spring immediately to mind as the most relevant application of AI, considering that the continent typically has high unemployment and fast-growing populations. Nevertheless, some countries in Africa have embraced robotics on the basis that it has an important role to play in their economic development. In this article, we explore this role and the ways in which Africa can best exploit the opportunities afforded by intelligent automation and robotics. It also highlights strategies to offset the threats posed by global factors, such as premature deindustrialization.

The Growing Impact of AI in Africa

There is an increasing awareness of the positive impact that AI will have on developing countries, including sub-Saharan Africa, in sectors such as agriculture, health care, and public and financial services [1]. AI has the potential to drive economic growth, development, and democratization, thereby reducing poverty, increasing education, supporting health-care delivery, increasing food production, expanding the capacity of the existing road infrastructure by increasing traffic flows, improving public services, and bettering the quality of life for people with disabilities [2]. AI can empower workers at all skill levels to be more competitive [3], [4]. Specifically, it can be used to augment and enhance human skills—not to replace or displace humans—and to do so at all levels, enabling average and low-skill workers to fit better in high-performance environments and take on more complex responsibilities.

Africa's biggest economic challenge is to equip large sections of its economy with average workers who are primed to perform tasks far better than most employees are currently managing to do. In South Africa, approximately 31% of employers cannot fill their vacancies [4]. AI will make technology easier to adopt and harness [1], [4]. In the health-care sector, AI helps address the shortage of doctors through telemedicine and access to medical supplies through drone deliveries [5]. In agriculture, AI (including machine learning, remote sensing, and data analytics) has the potential to improve productivity and efficiency at all stages of the value chain, enabling small-holder farmers to increase their income through higher crop yields and greater price control, detect and precisely treat pests and diseases, monitor soil conditions and target fertilizer applications, create virtual cooperatives to aggregate crop yields, broker better prices, and exploit economies of scale. Internet of Things (IoT) platforms may offer cost-effective ways to achieve those benefits [6]. For example, Microsoft is applying its Farmbeats platform [7] in developing countries by lowering the cost associated with densely deploying sensors, exploiting sparsely distributed sensors and aerial imagery to generate precision maps, and replacing expensive drones with smartphones attached to hand-carried, low-cost, tethered helium balloons [8].

Premature Deindustrialization

On the downside, factory and call-center work will slow as tasks are replaced by AI-enabled automation, including robots, which will add pressure to unemployment rates that are already high in developing countries, including those in Africa [5]. This will be exacerbated by growing populations, reducing opportunities still further. Africa's population is large and expanding fast: most of its people are young and urban with a median age of 19.5 years, compared to Germany (47.1), the United States (38.1), and China (37.7), and the youth population is set to reach 225 million by 2055 [5]. Kenya, Nigeria, and South Africa, for example, are projected to have approximately 5.5%, 8.5%, and 12.5%, respectively, of their workforce displaced by automation [9]. A report by the Oxford Martin School at the University of Oxford, United Kingdom, and Citigroup, New York, summarizes the situation in Africa in stark terms [10]:

> In most of sub-Saharan Africa, the manufacturing share of output has persistently declined over the past 25 years. The share of jobs in manufacturing is even smaller: just over 6% of all jobs. This figure barely changed over the course of the three decades

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leading up to 2008, while manufacturing employment in Asia grew from 11% to 16% over the same period.

While there are places with higher rates of displacement, the economies of these developing countries are particularly vulnerable due to high unemployment and the danger of premature deindustrialization [11], [12], whereby low-wage developing countries have fewer opportunities to industrialize before they achieve income levels comparable to those in developed countries. Thus, developing countries lose their competitive advantage in manufacturing to the lower-cost automation in developed countries and miss out on the economic benefits developed countries enjoy as their workforces move from low-value jobs to manufacturing to a postindustrial service economy. However, AI and robotics can help offset that trend, at least to some extent [12].

Consequently, developing countries are increasingly likely to be deprived of the opportunity for rapid economic growth produced by shifting workers from farms to factory jobs because 1) automation undermines the labor-cost advantage and 2) developments in robotics and additive manufacturing enable companies in advanced economies to locate automated production closer to domestic markets. The growing concern about premature deindustrialization in emerging and developing countries will require new growth models: "because skilled jobs are substantially less susceptible to automation, the best hope for developing and emerging economies alike is to upskill their workforce" [10]. Frey et al. suggest that there are inherent bottlenecks to automation: perception and manipulation, creative intelligence, and social intelligence. Those areas provide Africa with a window of opportunity when investing in R&D.

Combatting the Dark Side of AI

With the promise of a better future comes a danger that AI will make the situation worse; for example, by fomenting religious, ethnic, social, and political divisions through deep fake misinformation [5]. The lack of democratization in AI, including implicit and explicit bias in the training models, is a concern. At the same time, AI, in the guise of digital forensics and cybersecurity, can help to identify misinformation. It quickly becomes evident that, as Besaw and Filitz note, the deployment of AI is a double-edged sword [5].

There are several reasons that Africa can play an important role in advancing AI and not just exploit it for economic growth. For example, the elimination of bias and implicit discrimination in AI algorithms can be addressed in many ways. One is to increase the diversity of AI developers by raising the number of AI researchers and innovators in Africa and, thereby, increasing the likelihood of creating opportunities for AI to improve the lives of Africans [13]. In that context, the demand for data scientists, roboticists, and AI engineers will increase significantly [2].

Automation and Robotics

The deployment of robotics is increasing quickly. Frey et al. note that "the use of robotics … appears to have accelerated since the global financial crisis, seeing average robot sales rise at a compound average growth rate (CAGR) of 17% per year in 2010–14 (in fact, up almost 29% year over year in 2014 alone!) versus only an average CAGR of 3% per year in 2004–08" [10]. That growth is driven by rapid wage increases and aging populations in large manufacturing countries, a significant decline in the cost of robot hardware and software, and technological advances in robot vision, manipulation, navigation, and human–robot interaction. Those factors broaden the scope and usability of robotics so that even relatively low-wage countries, such has India and Indonesia, have increased their use of the technology [10]. Nevertheless, while robot ownership and operating expenses (US$10–20 per hour in the United States) are lower than typical labor costs, they are relatively high in Africa's developing countries.

Although it is clear that there will be more jobs in robotics, the numbers are lower than one might expect. Frey et al. [10] report that the International Federation of Robotics expects growth in robot use during the next five years to result in the creation of 1 million high-quality jobs. However, the number of research, design, and development jobs in robotics in the United States will increase by only 30,000 by 2022, from 133,000 in 2012, with technician positions rising by only 4,000, from 17,000, through the same 10-year period. Under the current circumstances, the numbers in developing countries are likely to be far smaller, so it is necessary to look for other ways of using robots to drive employment. For example, the use of robots can have a positive impact on industrial development in emerging economies by combining machines with additive manufacturing in the guise of 3D printing, which would lower the costs of prototyping and low-volume manufacturing and enable the manufacturing of new products whose high-volume production could become economically viable [12].

Apart from manufacturing, the use of robotics is set to increase in other sectors. The government of Rwanda announced plans to open a robotics cancer-training center in 2020 [15] in collaboration with IRCAD, the Strasbourg, France-based research institute for digestive cancer [16]. The center will offer laparoscopic training and R&D for minimally invasive surgery [17]. It has already recruited software developers and research engineers from local universities, leveraging graduate education in robotics and computer vision. There is, however, some way to go. While the number of robots sold increased globally by 15% in 2015, the total was lowest in Africa, with approximately 0.2% of the total, a figure that was 15 times lower than the continent's world gross domestic product share of roughly 3% [18], [19]. This is one aspect of the digital divide in Africa, which results from higher costs for capital and financing, for installing and operating robots, and for energy as well as poorer infrastructure, skills, and logistics and a lesser ability to adapt and maintain hardware equipment and software [18], [19]. When we consider that companies

typically invest in automation only when the cost of employing labor is significantly higher than installing robots, the situation does not look as bright. However, there are opportunities. African countries can avoid manufacturing sectors that are experiencing fast growth—electronics, computers, and transportation—and build industrial capabilities in less-automated sectors, such as food and beverages, basic metals, and wood and paper [18], [19]. The African Robotics Network [20] is instrumental in promoting that agenda through robotics-related education, research, and industry and by broadly defining robotics to include related areas, such as a automation, computer vision, signal processing, machine learning, and others.

The Rise of Drones in Africa

The use of drones in Africa is increasing. They are employed to survey elephants in Burkina Faso [21], combat rhino poaching in South Africa [22], and provide humanitarian aid by, for example, mapping and modeling flood risks in Dar es Salaam, Tanzania, Africa's fastest-growing city, where 70% of the people live in informal, unplanned settlements with inadequate infrastructure [23]. The use of drones for precision agriculture—using targeted interventions by applying the right treatment in the right place at the right time to optimize the use of available resources to increase the profitability and sustainability of agricultural operations, reduce negative environmental impacts, and improve the quality of the work environment [24]—is growing quickly in situations where crops are grown as a monoculture on large holdings [25]. Local companies, such as Charis UAS [26] in Rwanda and IAS [27] and Aerobotics [28] in South Africa, are addressing the challenges of deploying for small-scale, multicrop farms.

Drone technology for precision agriculture is a potential game changer for the African continent, albeit one that requires a skilled workforce with competencies that include planning flight itineraries, operating graphic information systems and data analysis software, interpreting data, and providing agronomic advice [25]. Significantly, this opens opportunities to develop systems that can automatically incorporate the expertise to identify appropriate interventions based on real-time sensor data (such as soil moisture, acidity, and nitrate levels and temperatures) that are gathered through IoT platforms, including Farmbeats [7]. Existing projects include the Third Eye project in Mozambique and Kenya, which uses low-cost drones to provide advice to farmers about irrigation and when to apply fertilizer and sow seeds [6], [29], resulting in an increase in crop production by 41%, a reduction of water use by 9%, and a 55% jump in water productivity [6], [25].

The use of drones in health care also has significant potential. For example, a Silicon Valley startup, Zipline, partnered with the Rwandan government to deliver more than 50 types of blood products to rural hospitals and clinics using custom-designed drones [30]. The Zipline drones have a range of more than 100 km; as of 2018, 12,000 units of blood had been delivered on 6,000-plus flights. More than 30 of the company's 100 employees are Rwandan. The authors of an *IEEE Spectrum* article sum up the Zipline operation well: "In the distance, we can hear the faint buzz of another Zip returning home after making its delivery of blood. Anywhere else on Earth, it would be futuristic. In rural Rwanda, it's just routine" [31]. (To see a Zipline drone drop blood packs at a clinic in rural Rwanda, see https://bit.ly/2pfnB6l.)

Education

The benefits of AI and robotics won't materialize without appropriate investment, education, and a legal framework to safeguard ethical research, development, and innovation [1], [13] as well as access to a deep pool of data relevant to Africa and initiatives to build trust [2]. It also requires a skilled workforce. The challenge for the education system in Africa—at every level, from the primary to the third and beyond—is to adapt to the needs for Industry 4.0 by focusing on elementary and secondary science, technology, engineering, and mathematics [18], [19] as well as third- and fourth-level curricula to give graduates the requisites to quickly adapt to the evolving AI landscape [6]. There is evidence that this is happening. For example, with sponsorship from Google and Facebook, the African Institute of Mathematical Sciences (AIMS) [32] launched a master's degree program in machine intelligence in Kigali, Rwanda, in 2018 [13], [33]. With the backing of the government of Rwanda, Carnegie Mellon University Africa (CMU-Africa) offers two master's programs (in electrical and computer engineering and information technology) that target key skills in AI (including cognitive robotics), machine learning, data science, software engineering, cybersecurity, telecommunications, and energy systems [34]; in addition, a dedicated master's program in AI and machine learning is in the pipeline. With the support of more than US$10 million from the African Development Bank, the Rwandan Development Board completed a new campus for CMU-Africa in 2019, as part of Kigali Innovation City [6]. Google opened an AI research lab in Accra, Ghana, in 2018. And the Deep Learning Indaba summer schools attract more applicants than they can accept from nearly half the countries in Africa [13].

The signs are positive at the secondary and primary levels, too. For example, 42 teams from 18 countries in Africa attended the fourth edition of the Pan-African Robotics Competition (PARC) in Ghana in 2019 [14] (Figure 1). In 2018, senior students at the Massachusetts Institute of Technology helped organize a three-week robotics camp focusing on agriculture, bringing together more than 40 students aged 14–17 (18 boys and 22 girls) drawn from 20 schools in Rwanda [35]. Start-up companies, such as Children's Creativity Lab [36], are looking to cater to younger children. The plenary talk by Ayorkor Korsah, Ashesi University, Ghana, at the 2015 IEEE International Conference on Robotics and Automation covered robotics in education in Africa [37] and

Figure 1. A scene from PARC 2019 in Ghana [14].

highlighted the technology's relevance to the continent. She surveyed the various activities for promoting robotics in Ghana, Kenya, South Africa, and Egypt and emphasized the need to find ways to empower young Africans to provide robotics solutions to their countries' problems.

Even then, having a good education is not enough: that education must be accessible to young Africans. Regrettably, most Africans cannot afford the high cost, and it falls to governments to put in place free or reasonably priced education and scholarship programs. Again, there is growing evidence that this is beginning to happen. For example, the government of Rwanda provides financial backing to reduce the cost of the CMU-Africa master's programs so that they are within the reach of students across Africa. Scholarships are provided by the Mastercard Foundation [38], Smart Africa Alliance [39], and Mandela Institute for Development Studies [40], helping to bridge the remaining funding shortfall. With help from Google and Facebook, the AIMS master's of machine intelligence program is fully funded [33].

Conclusions

Contrary to what one might think at first glance, there are opportunities for exploiting robotics in several sectors in Africa to promote growth and development and reduce unemployment and increase wealth. Several countries are taking steps to provide the advanced research needed to produce a skilled talent pool, but, clearly, more is needed. The likelihood of achieving Africa's full potential would be significantly increased if robot vendors were to seek ways to lower the barriers to entry by producing equipment at a price point that was feasible for adoption by the continent's companies, following the lead of others in related sectors, such as Microsoft's efforts to achieve low-cost IoT applications for precision farming [7] and South Africa's Ryonic Robotics' [41] low-cost robotic pipe-inspection crawlers. Given that "the entrepreneurial spirit of Africa's youth visible in many parts of the continent reflects how Africa is becoming innovative in finding locally relevant solutions to daily challenges in agriculture, health, and education" [6], advances in robotics and automation, leveraging Africa's well-advanced progress in adopting AI, should follow naturally.

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