Proc. of IEEE Africon'2011, 13-15 Sept., Livingstone, Zambia

A Role for Robotics in Sustainable Development?

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Abstract— **In a sustainable economic model, energy and material resources are limited. How would robotics need to be adapted to this model in order to play a useful role? This paper is an attempt at exploring the concepts for the role for robotics in sustainable development. Industrial robotics is often associated with an unsustainable economic model. However, robotics also provides qualitative benefits through its precision, strength, sensing capabilities and computing power. New applications and deployment models can be devised that improve sustainability and quality of life. These may require new approaches to the design of robots, robot-using systems and IT systems that employ methods of robotics and AI. Robotics for sustainable development is an exciting challenge where research and industry in both developed and developing countries can equally contribute and benefit.**

Keywords-Sustainable development, sustainable robotics, robot applications, education

I. INTRODUCTION

In developed countries, energy and materials have been almost free during their whole development process. This model is not available to developing countries [1], essentially because the world cannot support its whole population with the same level of energy and material consumption per capita as people in the developed world. This raises the question of the role and form of robotics in a more sustainable form of economy.

This paper is intended as a reflection with many unanswered questions. It is hoped that this will initiate a discussion, and if it emerges that robotics has a useful place in a sustainable world, this should hopefully be followed by case studies with financial support from governments, aid organizations, private enterprises and increased attention from academic institutions.

The rest of the paper develops the above question into whether robots are part of the problem, part of the solution, and the role of education in production, service, and education itself.

II. IS ROBOTICS PART OF THE PROBLEM?

A. Do robots support an energy-hungry mode of production?

Currently the initial investment in an industrial robot is recovered in 2 years. After that, the hourly cost of an industrial robot is essentially the cost of the energy consumed, typically 0.3US$ per hour, leading to an annual cost about 50 time smaller than that of a manual labourer in developed countries [2]. Thus, it makes economic sense to make use of robots in production. This will stay true for many years to come, even with rising energy prices. Many modern products require the high precision of robots, e.g. the assembly small components in mobile phones, which cannot be adequately achieved by human assemblers. An industrial robot typically consumes 150KWh per day, compared to 56KWh per household in Europe and 14KWh in Asia. The UK, for instance, has around 50 robots per 10,000 inhabitants and the fraction of total energy consumed by robots is very small. However, robots use electricity. This form of energy constitutes 25% of the energy used by UK households, but only 5% of household energy use in India, and much less in Africa [3]. Based on these figures and back-of-the-envelope calculations converting them to developing countries, in these places, energy consumed by robots in their current form cannot be neglected.

B. Does robotics promote over-production and under-employment?

Production made more efficient by the use of robots is an example of high specialisation: A small number of workers become very efficient at producing certain goods. These must then be traded at the right (low) price for other workers to be able to acquire them with the income generated by their own work. Specialisation pre-dates robotics, and robotics has not introduced fundamentally new elements in the market economy. However, robotics enables much higher levels of specialisation which could lead to instability: If fewer and fewer salary-earning workers are actually producing goods, fewer people will be employed and even very cheap goods will not find customers. This then leads to even fewer people being employed. It is an open question – worth studying - whether this is a real risk, as is how it can be avoided in a sustainable economic model.

C. Does robotics consume rare materials?

From this point of view, robots are not different from any machine with high precision and high durability parts, or from any computing device. Robot manufacturing will require sustainable solutions similar to those for other products. Also necessary to answer this is a life-cycle context that takes into account the economic and environmental cost of producing; maintaining; and disposing of the robots.

III. IS ROBOTICS A PART OF THE SOLUTION?

- Robots can help access new resources, for instance under the seas, or under lakes (e.g. underwater logging robot [4]), or conduct mining in dangerous environments. But this may be only delaying, if not accelerating, the moment where resources run out.
- Robots can help recycling resources. E.g. through their ability to sense the type of plastic using spectroscopic methods, which humans are not capable of.
- Robots can help reduce waste during industrial production, agricultural production and elsewhere in the food chain.
- Robots could enable production methods that generate less polluting by-products, although there is no obvious example of such applications yet, it seems likely, even if only by more economical use of materials and supplies.
- Robots could enable the repair of products which nowadays are thrown away when they malfunction. For example, the ability of robots to handle very small components could make it feasible to even repair and upgrade electronic appliances, computers and peripherals that are now discarded.
- In the agriculture domain, robots could help monitor soil conditions, the health of plants and animals and adapt actions to very local conditions, even plant by plant [5], in addition to a possible role in cultivating and harvesting crops
- Robots can help increased the yield in food production. For instance, use of a milking robot (e.g. DeLaval Milking robot) increases the number of litres per day that a cow produces, because the cow can access the robot at any time. An interesting point here is that it is probably the voluntary nature of the milking that is the key factor. In a country with low wages, it may be possible to only use the lessons learnt from robotics, e.g. a continuous milking service increases the yield.
- Robots, robotics and AI technologies can help manage small power generation units, e.g. biogas, solar, etc.
- Robots could save transport costs through flexible tele-presence, e.g. in health care. In such applications, robots could conduct local analyses of physiological samples.
- Similarly, robots could monitor water contamination, air quality and other environmental measurements, and improve health.
- The AI skills of robots could help in many ways and increase the effectiveness with knowledge provision and applications.
- The use of robot platforms could reduce the cost of technical education and increase its effectiveness.

IV. STEPS TOWARDS USING ROBOTS, ROBOTICS AND AI TECHNOLOGIES IN SUSTAINABLE ENVIRONMENTS.

A. New application and deployment models.

In the developed world, robots are typically used in large-scale production units, or for large-scale store or container management, or large surfaces cleaning. Personal robots have either limited functionality or will be expensive helpers for a minority of users. Such robots are useful in some aspects of sustainable economies, but new deployment models could also be devised, such as “community” robots, e.g. supporting access to health care and knowledge, or to execute punctual hard work, or to provide sensing when needed in the food production cycle, or to check the quality of a sample of water, or help calculate costs or dimensions for some design, etc. Robots could help manage the cycle of water, or local energy production, or inventory management, or transport rationalisation, etc. The key for such new models is the provision of services that are of value to the users. It is difficult to determine this from a distance and awareness of local conditions and of the possibilities of robotics is necessary for new solutions to emerge.

B. Redesigning robot components.

A robot is a multi-component device requiring multi-disciplinary knowledge, e.g. sensing, actuation and more-or-less intelligent control. New designs could make use of only some of the components in their current form. For instance, if electricity consumption through actuation is an issue, electric motors could be replaced by windup clockwork motors, an external combustion Stirling engine, or a biogas engine, etc. This would allow preserving the qualitative benefits of the robot, such as accuracy, while eliminating its reliance on high power electricity supply. Solutions of this type would require substantial research in mechanical engineering, mechanical-electrical energy conversion on small scales, and intelligent control.

C. New robotic concepts.

Not all components of a robot are needed all the time. Many of the tasks in section 3 rely on sensing. Sensors are generally light and consume little power. Thus, a sensing device could be carried around by a human operator. In other applications, such as repair, a human operator may only need the precision or the robot manipulator, but could use his/her own senses and decision functions. Here the robot would be merely a manipulator that could even use human power for actuation. In general, robotic concepts could be implemented in a variety of human-robot hybrid systems that combine the best of the human with the best of the robot.

V. ROLE OF EDUCATION AND TRAINING

21st century communities face intensifying development challenges and competing priorities for finite resources. Robotics and intelligent automation might help communities improve their quality of life and contribute to sustainable development. In the long-term, the adoption of robotics and intelligent automation as part of a development plan must be based upon documented opportunity, feasibility studies, and customized technology solutions designed for the local environment, preferably by local engineers, educators and policy-makers. The dynamics of the 21st century presents a myriad of challenges that require education collaboration be at the core of knowledge production and technology innovation.

Robotics for sustainability could develop from a combination of classical and sustainable technology and new application models. The latter are difficult to imagine and might best be developed by trial and error in the environment where the solutions are used. This relies on creative engineers and entrepreneurs fluent in the local environment who have a working knowledge of the principles of classical robotics and sustainable technology. Utilizing local resources and developing talent is crucial to the successful design and production of applied-technology development solutions. Local technologists and engineers 'have a unique understanding of the relevant problems as well as the cultural context, available resources, strengths and challenges that will influence the creation of innovative and useful solutions' [6]. The process may begin with a few collaboratively designed and implemented pilots and a small network of stakeholders. Educators occupy the essential role of turning this practical experience into a scalable body of knowledge and building appropriate curriculum and training programs that prepare local talent to design, build, and maintain these technology systems.

An initial step toward building and sharing knowledge for sustainable robotics development and application should be the development of a Community of Practice (COP) (Fig. 1). Communities of Practice are an effective instrument to encourage south-south and south-south-north collaboration around key curriculum and education policy & development topics [7]. South-south collaboration includes for instance sharing expertise on secondary education in the Middle East and North Africa (UNICEF workshop in Jordan). Encouraging examples of South-South-North collaborations include the Feed the Future Programme through which the US cooperates with Brazil to bolster Mozambique's agricultural productivity. Specifically, the US funds and helps to organize targeted education activities based on Brazil's agricultural-extension experiences. Some Brazilian seed varieties are well suited to Mozambique's climate, offering higher yields and better resistance to disease and pests [10]. COPs allow all to benefit from collective thinking which is especially relevant here because of the collective nature of developing technologies relevant to the developed world 'must not become the sole responsibility of developing communities; the developed world must play a crucial role in enabling such technologies' [8].

A Community of Practice is comprised of members 'who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis' [9]. This inclusive space would provide the multiple stakeholders (policy-makers, practitioners, educators) a valuable instrument for sharing and building knowledge about opportunities, successes, and barriers. UNESCO's International Bureau of Education describes the purpose of these knowledge sharing and laboratories as, 'an open and plural space, the COP facilitates opportunities to share visions, approaches, experiences, innovative practices, research results and analytical studies. It also offers concrete possibilities for jointly undertaking programmes and projects for institutional capacity building …' [7]. Communities of Practice can play an instrumental role in the transformation of learning practices from individual institutions to networked learning communities. Successful collaboration focuses on deepening knowledge, applying innovative solutions, and providing access to resources and peer-to-peer mentoring. Institutions of higher education play an important role by modelling this behaviour – creating multi-national research and teaching teams focused on innovation and problem solving.

Figure 1. Community of Practice Learning Cycle [9].

Specially, in terms of the application of robots, robotics, and robotics and AI technologies for sustainable development, establishing a Community of Practice is especially vital in these exploratory stages and might aide in the

- Identification of national, regional, and global industrial and educational strengths and needs the identification of potential local and global private-public partnerships to address both.
- Formation of a focused international network working in concert to address fundamental needs, analyze data, and propose solutions.
- Design implementation, documentation of collaboratively designed pilots.
- Development of regular face-to-face visits, virtual meetings, and planning for study visits.
- Integration of new knowledge into curriculum and design of academic programs, faculty capacity building programs, and short courses.

VI. CONCLUSION

In a sustainable economic model, energy and material resources are limited. Robotics can contribute, but will need to be adapted to this model in order to play a useful role. Industrial robotics and automation currently play a quantitative role in increasing the productivity of human workers, which could actually have a destabilising effect on economics. However, robots also make a qualitative contribution to production. Sustainable productivity management does not, in principle, preclude the use of robots. Firstly, robots have skills such as strength, precision and sensing often surpassing those of humans. These skills allow the production of useful goods or services and it would not make much sense to renounce such qualitative benefits but 'often' is not 'always', which reminds us of the advantage of hybrid 'man-plus-machine' approaches. Secondly, robots can be redesigned to make use of sustainable energy and material resources. Thirdly, as just noted, new robotic system application models can be conceived of where in a human-robot partnership constitutes a production unit, exploiting the capabilities of both partners. Fourthly, new applications of robotics can emerge, that support a sustainable economic model. One can think of application domains such as energy and resources production, the food chain, and recycling. However, the most useful applications are still to emerge. This can probably only be enabled by educated and enterprising engineers aware of local needs and conditions. Finally, in-as-much as sustainability includes a large element of local self-reliance, the potential of robots, robotics and AI technologies, and AI to improve, accelerate, and support sustainable development depends upon creative and relevant education programs. This is, despite its last place in this list, the opportunity that will have to be completed before the others are actually accessible.

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