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A Cambrian Explosion of Robotic Life

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Abstract: The main objective of this paper is to argue that we, as a civilization, are in the beginnings of a *Cambrian Explosion of Robotic Life*. In order to give support to this argument, we present a line of thought that begins with a very brief technical account of what has been so far the design and development of robots. Then, we assume that the emergence of recent disruptive technologies, such as Kinect, an information technology device developed by Microsoft Corporation, generated a simple and low cost solution to the problem of visual computing, turning the design and development of robots for simple applications barely a question of hardware construction and software development for control. As the design and development of robots for less complex applications do not need advanced computational intelligence, these tasks only require control commands that respond to real world stimuli; in other words, it is just a question of software design and development. For this reason, the design and development of robots have become a simple and common undertaking, which is giving birth to a global explosion of robotic life, a phenomena comparable to the Cambrian Explosion of Life which our planet experienced millions of years ago.
Key words: Robots; Hardware; Software; Motion; Information technology; Computer vision; Kinect; Human machine interface (HMI); Emerging economies; Cambrian Explosion; Disruptive technologies

As properly described in Choset et al. (2005), since the beginnings of civilization man has had a fascination for a human-like creation that would assist him. Societies in the early part of the first millennium were engaged in slavery and used those slaves to perform tasks which were either dirty or menial labors. Man had discovered mechanics and the means of creating complex mechanisms which would perform repetitive functions such as waterwheels and pumps.

In 1921, Czech writer Karel Čapek introduced the word “robot” in his play *R.U.R. (Rossum's Universal Robots)*. The word “robot” comes from the word “robota”, meaning, in Czech, “forced labour, drudgery” (Spong, Hutchinson, Vidyasagar, 2005). In the early stages, robots technological advances were slow and they were complex mechanical machines, generally limited to a very small number.

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In recent years electronics became the driving force of development instead of mechanics. Since then we have seen robots finally reach a more true assimilation of all technologies to produce robots such as ASIMO, the humanoid robot created by Honda Motor Company Ltd. (2010), which can walk and move like a human.

However, although commercial and industrial robots are now in widespread use performing jobs more cheaply or with greater accuracy and reliability than humans, and despite they are also employed for jobs which are too dirty, dangerous or dull to be suitable for humans, their total population is still limited to thousands of units, when compared to humans and other species of beings. Two of the most recognized technical obstacles of a more spread usage of robots into daily tasks are limited vision and artificial intelligence, which have constrained robots comprehension of tri-dimensional real world surrounding them.

The emergence of recent disruptive technologies, such as Kinect, an information technology device developed by Microsoft (2010a), seems to be the removal of these technical obstacles. By generating a simple and low cost solution to the problem of visual computing, this technology turned the design and development of robots for simple applications barely a question of hardware construction and software development for control.

As the design and development of robots for less complex applications do not need complex computational intelligence, these tasks only require control commands that respond to real world stimuli; in other words, it is just a question of software design and development. For this reason, the design and development of robots have become a simple and common undertaking, which is giving birth to a global explosion of robotic life, a phenomena only comparable to the Cambrian Explosion of Life which our planet experienced millions of years ago.

The main objective of this paper is to argue that we, as a civilization, are in the beginnings of a *Cambrian Explosion of Robotic Life*. In order to give support to this argument, we present a line of thought described in five procedures. In section 2 we present a very brief technical account of what has been so far the design and development of robots. In section 3 we argue that Microsoft launched Kinect, an information technology device that was aimed at broadening its Xbox 360's audience beyond its typical gamer base, but it also gave to humanity the opportunity of exploring a potential new market of trillions of dollars: the *general purpose robotics* market. In section 4 we briefly present what we think is a *Cambrian Explosion of Robotic Life*. Section 5 describes how we perceive the non-humanoid robotics segment. In section 6, we deal with the role that Emerging Economies can play in the future world of robotics. And, section 7 brings our final conclusions.

WHAT HAS BEEN A ROBOT SO FAR

From their early stages to the recent age where electronics became the driving force of development instead of mechanics, the design and development of robots can be easily recognized by a very simple equation:

Robots = Hardware + Software + Motion (1)

Hardware (Bräunl, 2008) is the physical part of a robot, comprising its electronic components, printed chips, engines, cables, wires, hydraulic mechanisms, cameras, sensors, actuators, processors, micro controllers, batteries, etc. In short, it is a combination of electronic engineering areas plus mechanical engineering areas.

Software (Spong, Hutchinson, Vidyasagar, 2005) is the controlling part, the logical part. It involves artificial intelligence programs, computer vision and control or automation systems. In short, it is computer science plus control systems.

Autonomous motion (Choset, et al., 2005) is the fundamental part of a robot. It is the dynamic dimension that permits a robot to undertake a task in the physical world, for example, to hold a cup, walk, lift a box, select pages of a book, etc. In short, it is mechanical engineering plus control and automation systems.

The operational workflow of a robot can be described as follows. A sensor captures a phenomenon in the physical actual world. This phenomenon is then measured and transformed into digital information. This information is processed by controlling software. If this information is complex, then it is processed via artificial intelligence or vision. Then, a decision or diagnostic about the phenomenon is built. After that, control software is informed about the diagnostic, and a command is sent to the triggers. Engines, motors and/or hydraulic mechanisms are put in action generating a movement or reaction to the original physical phenomenon.

What then can be said about the knowledge domains of the design and development of robots? Firstly, the hardware part issues of electronic engineering are already well understood, and extremely complex electronic systems have already been built with relative simplicity, as computer and network boards, processors, electronic components, sensors, etc., which integrate computers, smartphones, radio systems, satellites, etc. Mechanical engineering is also well understood, and the examples are automobile vehicles, planes, ships, automated factories, heavy machinery, mechanisms with complex and small size engines, such as watches, printers, electrical tools, etc.

Secondly, in the software part issues, artificial intelligence (Russel and Norvig, 2009; Haykin, 1998) and computer vision (Bovik, 2005; Davies, 2004) have been recently researched intensively, and are well developed. However, they are still constraint factors for the application of robots in complex tasks that require accurate vision, comprehension and intelligence. Controlling software (Nise, 2007) are well understood, and the examples are automobile assembly lines, automated charge and discharge of loads in airports, scavengers, mining equipment and other heavy machines that are easily operated via controlling systems.

Finally, with regards to motion, mechanical and electronic engineering already allow motion accuracy that is of large domain, such as automated industries.

In short, the two major obstacles for the usage of robots in daily tasks have been limited vision and artificial intelligence, which limit robots comprehension of tri-dimensional real world that surrounds them.

KINECT: THE IMPACT OF DISRUPTIVE TECHNOLOGY

Kinect for Xbox 360, or simply Kinect is a “controller-free gaming and entertainment experience” by Microsoft (2010a, 2010b) for the Xbox 360 video game platform. Based around a webcam-style add-on peripheral for the Xbox 360 console, it enables users to control and interact with the Xbox 360 without the need to touch a game controller, through a natural user interface using gestures and spoken commands. The project was aimed at broadening the Xbox 360's audience beyond its typical gamer base.

This is the “official” or apparent purpose of Kinect (Microsoft, 2010a; Geiss, 2010). What is not said or written is that Microsoft in fact created a simple and cheap solution for computer vision problems, turning the design and development of robots for simple applications only an issue of hardware construction and software control programming that are integrated with Kinect. In other words, from generic robotic hardware platforms, it is now only necessary to program the controlling software to ignite the hardware and to process the information generated by Kinect. This is so because robots for less complex applications do not need complex computational intelligence; they only require control commands that respond to stimuli from real world. And this is only an issue of software design and development.

Actually with Kinect Microsoft began a revolution in human machine interface (HMI). Mouse, keyboards, joysticks, touch screen and even multi-touch screen look like obsolete, compared to Kinect´s ease of use. Kinect is a new “platform” for human machine interaction, and represents a new paradigm. Hackers all over the world have noticed it, and its protocol has already been broken and many applications using Kinect are being created.

We believe that Microsoft envisaged one commercial aspect with this device but also gave birth to a broader economic scenario. It seems that in order to dominate the market for video games, Microsoft launch Kinect wishing to beat sales from Nintendo Wii (Nintendo, 2010) and Sony Playstation Move (Sony, 2010), a market of billions of dollars per year. But it has also overcome the problem of basic robotic vision, giving to humanity the opportunity of exploring a potential new market of trillions of dollars: the *general purpose robotics.* Everybody can now make functional robots, with stereo vision, at a relatively low price, by using

Kinect. It is our opinion that Microsoft could hold this launch for one or two years, and by doing such a move, it could be the first and the only firm to produce robots for simple daily applications

Microsoft has not officially launched Kinect as an HMI for computers and for other types of devices, except from Xbox. Maybe it will soon offer software libraries for developers all over the world to use Kinect as a general purpose HMI or vision device.

There are rumours that Microsoft Windows 8 will come with support for Kinect (Wikipedia, 2010). Meanwhile, more than 300 applications are already in YouTube using Kinect hacked protocol as HMI or as robotic vision (KinectHacks.net, 2010). One can imagine the number of applications that are currently being developed in secret or that are simply not being broadcasted.

Another aspect is that now Kinect has shown how to solve simple computer vision problems, then other firms (such as Sony, Nintendo, etc.) will follow and soon will offer their similar devices, and from competition prices will fall.

By all exposed, it is possible to argue that Kinect is a "disruptive technology", an innovation that breaks with the existing market, term coined by Christensen and Bower (1995, 1997).

A CAMBRIAN EXPLOSION OF ROBOTIC LIFE IS IN CURSE

Everyday several new videos are posted with robots using Kinect, and we are not far from three months it has been launched. There are already libraries of software for processing data outputted from Kinect, see (OpenKinect, 2010), for example.

That is the reason why we can say we are experiencing a "*Cambrian Explosion" of Robotic Life*. In the Cambrian period nature created a "basic platform" for the existence of complex life, multi-cellular and constituted by organs. From mutations of those complex beings, suddenly thousands of other beings emerged, all of them with innate survival capacity. Furthermore, Parker (2003) shows that the Cambrian explosion was triggered by the sudden evolution of vision in simple organisms. After eyesight evolved, prior close-range predator affairs, became more active once predators could see their prey from a distance. Suddenly, preys adapted and evolved new defences strategies to survive, leading to new species differentiations.

Therefore, it can be argued that a similar phenomenon is happening with robotics, as the basic technological conditions for robots being functional are already created, as the last obstacle for this (the vision issue) has been overcame by Kinect. Now the challenge is to put imagination to create robots for all ends. Several software libraries and drivers are available, most of them are free software, and the basic hardware can be bought via Internet at low cost, see Tables 1 and 2, respectively.

Table 1: Robot Software Libraries and Drivers

Initiative Name	Web Site
MRPT	www.mrpt.org
Webots	www.cyberbotics.com
Microsoft RDS	www.microsoft.com/robotics
The Player Project	playerstage.sourceforge.net
OpenSLAM.org	openslam.org

Table 2: Robot Hardware Stores

Company Name	Web Site
Adept Technology Inc	www.mobilerobots.com
Robot Store (HK)	www.robotstorehk.com
RobotBooks.com	www.robotbooks.com
TheRobotShop.com	www.therobotshop.com

Actually why Kinect accelerated/anticipated an explosion of robotic life? Kinect is now commercially available to anyone. Without Kinect not everyone could have access to the libraries of vision algorithms available; even if they were open code or free software, a solid knowledge basis on computer vision, artificial intelligence, pattern recognition, imaging processing, etc., would be necessary to use such libraries and, therefore, to create software that would be able to understand real 3D world. If this was easy, one could expect there would exist other kinds of Kinects, robots with accurate vision, or human machines interfaces with control by gesture everywhere. However, practically there is nothing in this area from the commercial point of view, apart from some experiments in the scientific/academic domain.

As an entertainment tool, Kinect propels its use in other applications, since it is fun to solve problems with it. It is practical to use it, unlike to vision libraries such as OpenCV (Bradski and Kaehler, 2008), which are free and advanced, but are more difficult to use and require prior knowledge.

Kinect can be used as an accessory device (ex. webcam), but it is necessary to stress that it is more than that. Accompanied with software libraries (OpenKinect, 2010) it delivers as output processed data, not raw data, like webcams. It performs depth analysis, identifies objects, detects people in the scene (up to 6 people), and follows motions up to 20 parts of the bodies of two of those people (Wikipedia, 2010). In other words, it does not only delivers a scene or an image; it offers an understanding of the scene and informs: "there are two people in front, one at the right and the other at the left, they are moving in such a way, the person at the right raised its right arm, there is an object of volume *x* behind it, and there is other object of volume *y* and size *z* in front of the two". In short, Kinect does a scene analysis. Machines automatic analysis of scenes is one of the most difficult problems of image processing and computer vision (Bovik, 2005), so it is reasonable to believe that Kinect is more than a simple accessory device.

Last, but not least, the start up timing of an application with Kinect is shorter and anyone, with reasonable knowledge on software programming and few resources can play controlling robots, something that was only reserved before to scientists and researchers of computer vision, artificial intelligence, electronics, and robotics.

For all these reasons, we think an explosion of robotic life is beginning and is taken place at this very moment as a general, and accessible to all, global phenomenon!

NON-HUMANOID ROBOTICS

Humanoid robots that could undertake complex tasks will delay some years to arrive at the market. But non-humanoid robots for simple tasks can already be built. These are the robots most influenced by Kinect and will be the vast majority of "life species" of the Cambrian Explosion of Robotic Life.

At first, it might not be clear the applications for non-humanoid robots, but with a few comparisons with other market areas, we may see the dimension of this new market. See comparisons below:

1. Today there are appliances for everything, even some considered to be useless, such as: bread toasters, coffee makers, sandwich makers, juice makers, multi-processor, electric knife, range juice squeezers, electrical toothbrushes, and so on. Even having stove, oven, or other more general appliances that could do the job, we still buy specific and specialized ones.

2. Furthermore, today we have microprocessors chips for thousands of applications, such as: ABS breaks, microwave ovens, motion sensors, mobile phones, video games, watch radio, car alarms, etc. Who could anticipate that there would be market for design and fabrication of chips after the emergence of Intel Corporation, which dominates the market for computer microprocessors up to now, and without any signs of failure in this dominance?

3. Soon, with the Internet of Things (Yan, et al., 2008), we will have several electronic devices connected in networks for the most diverse ends. Many unthinkable at the moment and even considered useless nowadays.

4. From 2 to 20 years we will have *Robots for Things*. They will be robots for the most diverse ends, as we have the electric domestic appliances for everything we can imagine. For the most part there will be robots considered today useless, but that certainly will exist. The vast majority of the robots will not be humanoids because those will be the most expensive and utilized only when is necessary. Examples of non-humanoid robots could be: robots for painting streets; robots for painting walls; robots for cleaning

ceilings; robots for cleaning glass windows in skyscrapers, robots for cleaning streets, robots for identifying electricity distribution failures in power grids; robots for cleaning pipes; shower robots; robots for changing automobile tires; robots for inspection; robots for surveillance; robots controlling agricultural plagues; robots for mining and oil exploration; robots for guiding blind people; and, thousands of other daily applications.

Therefore, the non-humanoid robotic will explode! The humanoid robotic will be dominated by large corporations, but the non-humanoid robotic will be of public domain.

It is likely that in the future no single firm can dominate the technology for non-humanoid robotic. We will see a proliferation of firms as we see nowadays in the software market. It will be an idea of public domain.

EMERGENT ECONOMIES AND THE ROBOTICS

We believe that the robotics future of Emerging Economies, like Brazil and others, lies in exploring the non-humanoid robotics. In the same manner that these nations created software industries with several firms, they can be able to create a great number of businesses geared to produce controlling software for this robotics, and to assemble its hardware, which will continue to be designed overseas, perhaps still in Developed Economies.

Instead of investing in innovation and creation of new technologies for the robotics foundations, we think emerging economies should concentrate their efforts into the application of robotics.

There will be many opportunities as in the Internet of Things, since the robots will also be part of it, and they will form the universe of the *Robots for Things*.

Soon there will be the *general purpose robot*, requiring only to program it, in the same way we do for computers. These robots only demand controlling software, and there will be several manufacturers, which will dispose software libraries to help the development of controlling softwares. Today this is accomplished with operating systems such as Windows, Mac OS, IOS, Android, Linux, for which development libraries are available. The same will occur with *general purpose robots*.

In sum, the *Cambrian Explosion of Robotic Life* is welcome for emerging economies. The explosion will make robotics components cheap and accessible, and will enlarge applications possibilities. Countries like Brazil can be one of the first to focus in these applications. We estimate there will be 10 to 20 years of robotic explosion. It will be much like the boom of the Internet some years ago, where anyone with one idea could raise money, until markets clear.

CONCLUSIONS

In this short paper we argued that, as a civilization, we are in the beginnings of a *Cambrian Explosion of Robotic Life* that would assist mankind to proliferate "forced labour", in the good sense pointed by Karel Čapek's *Rossum's Universal Robots* play. We defended this point by presenting a line of argumentation that relies in the recent technical and commercial advances in the field of information technologies.

This robotic explosion has begun by the emergence of Kinect, an information technology device developed by Microsoft Corporation. It has produced a simple and low cost solution to visual computing problems, turning the design and development of robots for simple applications barely a question of hardware construction and software development for control.

Kinect is an outstanding device, accompanied with proper software libraries, it delivers as output processed data, not raw data, and it performs scene analysis, a very difficult computer vision task. The start up timing of an application with Kinect is shorter, and anyone with reasonable knowledge on software programming and few resources can play controlling robots. Kinect is a disruptive technology, an innovation that breaks with the existing market.

Microsoft has not officially launched Kinect as a general purpose human machine interface or robotic vision device, but maybe it will soon offer software libraries for developers to use Kinect broadly. Microsoft has also not been the first firm in the market for *general purpose robots*, but it gave the humanity an unprecedented impulse in what we called here the *Cambrian Explosion of Robotic Life*.

Emerging Economies have a role to play in this robotics explosion. Their place is not in the design of robots, but in the application and programming of these robots. Creation and application markets for robotics are both gigantic.

As future work we might ask, what then remains to be analysed? We still have to assess the impact of this robotic explosion for humanity. Its is necessary to understand the gain for humanity in terms of quality of life, jobs, new services, new technologies, lives safe, practicality, and so on. Several trillions of dollars can be generated. Thousands of new factories can be built, and new design and development offices can be opened. How these movements can change the global economy?

One thing, for sure, we can be certain: the only way to predict the future is to design it. So, *let´s "code" robots!*

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