MSc Program

Engineering Management

GLOBAL TRENDS IN COST ORIENTED AUTONOMOUS ROBOT MARKET

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November 2011, Vienna, Austria

Affidavit

I, **SIAVASH DEZFOULI**, hereby declare

1. that I am the sole author of the present Master's Thesis, "GLOBAL TRENDS IN COST ORIENTED AUTONOMOUS ROBOT MARKET ", 72 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted this Master's Thesis as an examination paper in any form in Austria or abroad.

Vienna, Nov. 2011

Signature

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My deepest thanks to my Mom and Dad who have always been my supports in every stage of my life and extended special sense of gratitude to my wife for her kindness and enduring in our life.

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ABSTRACT

The Robotic market is broken down into different segments such as industrial, domestic service, professional service, military, security ,space applications and etc. which industrial applications currently have the largest market. The study of interactions between human and machines is an important aspect in the adoption of control technologies involving both technical issues and social implications. Human–machine studies consider all conditions, where humans (individuals as well as groups) use, control or supervise tools, machines or technological systems.

As engineering science gets better and better, life will get easier too. The latest trends in ‘robotic intelligence’ are towards imitating life. Biomimetic robots, evolutionary robots, emotion controlled robots are just some new research ideas. Although these approaches are very different in their nature all have a common goal, to improve the adaptivity and learning capabilities of robots, ‘breeding’ a new generation of robots with better ‘survival’ chances in their specific operational environment. But still the biggest challenge in robotics markets for the next decade will be to find the proper balance between human-assisted systems and fully autonomous ones, thus to combine high technological capabilities with social expectation and low cost requirements.

The main goal of my thesis is to explore demands of robotic market (pull and push technology), new trends and technologies of robots and main poles of robotic market across the world. The impacts of robotics in engineering which will help to accelerate the global trends in this field will be described and demonstrated. The latest advances in robotic market, humanoid robot trends, new opportunities, related works and future research directions and visions in this special field are evaluated and presented.

1 INTRODUCTION

Robotics has been named a key science of the 21st century. . Robotics can be regarded as a typical and representative part of Mechatronic, as a cutting edge technology in this rapidly expanding research field (Schweitzer, 1996). A blend of mechanics and electronics, Mechatronic has come to mean the synergistic use of precision engineering, control theory, computer science, and sensor/actuator technology to design improved products and processes. The means and methods of Mechatronic and robotics are spreading to other engineering sciences, and to medical areas, offering huge chances for novel products.

The development of robots into intelligent machines touches upon issues such as the self-understanding of humans, upon socio-economic, legal, and ethical issues. Robotics can be regarded as a typical and representative part of Mechatronic, as a cutting edge technology in this rapidly expanding research field (Schweitzer, 2003). Mechatronic combines in a synergetic way the classical engineering disciplines mechanical and electrical engineering and computer science, leading to new kinds of products.

Robotics has, for at least four decades now, been widely used in engineering industries, which account for some 70% of all industrial applications (EUROP members, 2005). Typical industrial use involves the car industry and manufacturing of electronic goods. In the car manufacturing, the introduction of robots has in particular enabled a more homogenous quality of products and at the same time contributed to a dramatic cutting of costs.

Last decade's big increases in computing power and falling prices for laser scanners, motion sensors, software, chips, and other electronic components have made all manner of robots far more intelligent and flexible. The industrial robotics market has experienced a steady growth over the last decade. There are 16 industries which are most reliant on robotic technology, including aerospace, chemical and fuel processing, defense, education and research, food processing, home care, medicine and surgery, pharmaceutical manufacturing and textile/clothing manufacturing. Large enterprises in high-volume markets have remained competitive, thus maintaining qualified jobs by increasing their productivity through, among other things, incrementally adopting robotics. While robotics has become a synonym for competitive manufacturing, so far robots have been mainly used in the automotive and electronics industries which, including their supply chains, account for more than 60% of annual total robot sales (Haegele, et. al, 2005).

Therefore robot technology has been mainly driven by the needs of these high volume market industries. It is recognized that future manufacturing scenarios throughout all industrial branches will have to combine highest productivity and flexibility with minimal manufacturing equipment life-cycle-cost. This paradigm is particularly valid for today’s small and medium sized productions as these are particularly prone to relocation due to high labor costs.

Automation and robotic market has wide-ranging commercial implications. Robots are used extensively in the automotive industry, primarily for welding, painting and material handling applications. The electronics, aerospace, metalworking and consumer goods industries are also major robot users. Integrated factory automation systems, to which robot technology is key, affect nearly all types of manufacturing. In the near future, productivity and competitiveness in these industries will depend in large part on flexible automation through robotics.

Current robot automation technologies have been specifically developed for capital-intensive large volume manufacturing, resulting in relatively costly and complex systems, which often cannot be used in small and medium sized manufacturing (Bischoff, et al., 2005).

Thus, future robot systems will not be simple extrapolation of today’s technology but rather follow new design principles required by a wide range of possible applications (application pull). Novel technologies, particularly from the IT world and mass markets will have an increasing impact on the design, performance and cost of industrial robot automation (technology push).

In this thesis the global trends in robotic market mainly in Asia, Europe and U.S.

respectively are statistically described. Worldwide trends in robotic technology due to needs and demands of robotic consumer and market are evaluated. Challenges in robotic industry specially industrial and service robots are focused and compared.

1.1 Thesis Structure

This research can be classified in three main factors:

- Global trends in Industrial robotic market
- Global trends in service robotic market
- New trends and opportunities in robotic market

and evaluated and compared statistically and technically in three main areas in worldwide robotic market respectively such as:

- Asia (Japan & Korea)
- Europe (Germany as a leader)
- U.S.

2 PROBLEM FORMULATION

2.1 Research Objectives

This thesis starts with trends in robotic market including relation between low cost automation and productivity, current trends in robotic and its market across the world. Discussion and reports on industrial robot, demand of industry, importance of robotic, and 2010 as a sharp recovery year of robotic market are presented. It continues to describe and explain challenges, demands and investment of industrial and service robots in automated and none automated countries.

Global trends in robotics market due to producers and consumers are evaluated and listed. The global supply of industrial and service robot including the forecast from 2011 till 2014 in Asia including Australia, Europe and U.S. are discussed. Expectation, potential, rate of sales, biggest changes, growth and demands in robotic market globally are compared and explored.

It focuses on trends, challenges, needs and potential of industrial and service robot in three main global markets such as Asia, Europe and U.S in chapter 4.

In chapter 5 it discusses and describes the trends in humanoid robot and new opportunities in robotic.

Finally in last chapter the trends in autonomous robot market and main reason to invest in robotic market are presented and summarized.

2.2 Data Collection and Statistical Results

Forecasting and statistical results which are presented in this thesis are based on the latest data from:

- ABI Research: is a market intelligence company specializing in global connectivity and emerging technology hence the statistics
- Ministry of technology and Economics of South Korea,

- IFR: International Federation of Robotic (Statistical Department)
- WTEC : World Technology Evaluation Center
- SRAR : Strategic Research Agenda for Robotics
- JRA: Japan Robot Association
- EUROP: European Robotic Platform

3 TRENDS IN ROBOTIC MARKET

Instead of building machines that can do the work of humans, we should build machines that can do the work which humans cannot do, or do not want to do.

The potential market for robots is expanding, particularly for those that can perform tasks normally done by older workers and homemakers. It can be stated that any technical progress in robotics will quickly spread over to products of everyday life and may eventually initiate further progress. Automotive technology for modern cars, for example, in making advanced use of sensors for controlling their dynamics and assisting in safe driving are following ideas from robotics . In addition to that, the need for low-priced sensors in mass-produced cars has subsequently spurred the industrialization of micro technology in a very sustainable way.

Methods of robotics and Mechatronic serve, beyond the individual product, as guidelines for the development of complete systems. Thus, the name system robotics or embedded robotics has been coined, to describe the integration of sensors, control, actuators and information processing into a system. This can be a car, an automated traffic control system, a military air defense system, medical service and human care systems, or the safety and energy management system of a building.

3.1 Cost Oriented Autonomous Robot & Productivity

The main aim of low cost automation is to increase productivity and quality of products and reduce the cost of production, and not reduce a labor.

What is the concept of cost oriented? It does not mean poor quality or performance, the concept can be boded as a selection of optimized methods intending at exploiting tolerance of inaccuracy or unreliability to achieve durability, robustness, and, in the end, low cost solutions. High costs and complexity are suspected to be the main reasons explaining why robots have not spread widely in industry as it was foreseen some decades ago. Robots have not followed the dramatic price and performance improvements of computers while at the same time they remain complex and close systems. Cost is an important element in choosing to move a factory overseas. There is key evidence that demonstrates automation and robotics can provide the cost savings companies are looking for without outsourcing.

Low cost automation is a technology that creates some degree of automation around the existing equipment, tools, methods and people, using mostly standard components available in the market. Cost effective automation enables the industrialist to improve his manufacturing methods and efficiency without going in for costly machinery. Low cost automation should not be regarded in terms of a specified maximum capital outlay, but as an approach to automation using equipment and control devices that are, in general, both technically and economically, within the scope of the company concerned.

Cost oriented automation involves the implementation of an automation system in product. This should be as easy as possible and besides it has to facilitate maintenance. Maintenance is very often the crucial point and an important cost-factor to be considered. A standardization of components of automation systems could also be very helpful to reduce cost, because it fosters the usability, the distribution and innovation in new applications.

On the other hand the improving and operating automation systems is another cost-factor of productivity and competitiveness in manufacturing plants, quality control systems and robotics area. The miniaturization and power reduction of the processors made mobile computing possible and with it increased the brain capabilities of mobile robots.

The development and introduction of a standardized wireless communication protocol transformed the robots into internet plugged system accessing all available information within the net. While energy saving, miniaturization and intelligence become hallmarks of today's industrial automation and robotics new developments in the area of new light materials, sensor less control and out-door navigation will improve the robots of the next decade.

Light manipulator and the improvement of haptic interfaces installed on mobile systems will increase the capabilities of today's service robots. Not only one could be virtually at home by monitoring and requesting services from the home butler remotely, but many elderly peoples could stay longer in their own house with a 24 hours support from a robot nurse that helps them, monitors their health status, calls the doctor, family, etc. in case of an emergency (Peters, 2010).

Automation and cost oriented robots provide a variety of benefits to the manufacturing community including improved efficiency, better quality, reduced piece price, minimized risk and improved control of operations. Of all the forms of automation, robots prove to be the most flexible and offer more opportunities for companies to maintain profitability.

3.2 Current Trends in Robotic & Market

Currently robots are used for jobs that are boring, dirty, or dangerous; or for tasks that require more speed, precision, or endurance than a human can provide. They perform almost all welding, painting, and assembly tasks in the automotive industry and have become a basic element of production in industries ranging from electronics to wood products.

According to world robotics, a 2008 report published by the International Federation of Robotics, the estimated number of industrial robots installed worldwide is more than one million—50% in Asia, 33% in Europe, and 17% in North America (Noor, 2008). An assessment of the international state of robotics research and development published in 2010 by the nonprofit analysis World Technology Evaluation Center (WTEC), found that the U.S. was leading in robot navigation in outdoor environments, robot architectures (the integration of control, structure, and computation), and in applications to space, defense, underwater systems, and some aspects of service and personal robots.

Japan and Korea lead in technology for robot mobility, humanlike robots, and some aspects of service and personal robots (including entertainment). In Japan, the

Ministry of Economy, Trade, and Industry has sponsored robotics activities for a long time. A national technology roadmap by the trade ministry called for one million robots to be installed throughout the country by 2025. To alleviate a workforce shortage in the country, robots are expected to fill the jobs of 3.5 million people by 2025. The Japanese government also estimates that the nation may save as much as $21 billion on insurance payments in the same year by using robots to monitor the health of elderly people.

In South Korea, a 10-year robotics initiative was launched along with a detailed roadmap to make the country the second-largest provider of robotics in the world, after Japan. Robot land, a theme park being built near Seoul, is expected to open in 2013. The country's forecasts include placing a robot in every household by 2020 (*Lobeck. and Noor, 2011)*.

Europe led in mobility for structured environments, including urban transportation. Europe also has significant programs in elder care and home service robotics.

Australia led in commercial applications of field robotics, particularly in such areas as cargo handling and mining, as well as in the theory and application of localization and navigation. U.S. lost its preeminence in industrial robotics at the end of the 1980s, and nearly all its robots for welding, painting, and assemblies are imported from Japan or Europe.

In 2005, the European Robotics Technology Platform was formed to strengthen links between academia and industry, and to develop a research agenda of European robotics (Isasi, www.robotics-platform.eu, 2011).

Companies developing new products and services incorporating intelligence into machines, integrating emerging robotics technology into existing products, and using robotic technologies to gain competitive advantage such as electronics, mechanics, digital, design, telecommunication, personal assistance and very broad filed of opportunities in city infrastructure (transport, tourism, security, etc.), communication, media, health, education, home equipment, monitoring, security, and digital entertainment.

Trends in robotic pending on their functions and destinations are categorized in:

- Industrial robot systems
  - To achieve high-quality and cost-effective flexible manufacturing and logistics in all major industrial branches
- Service robots
  - To be found in all domains of our life: in domestic and leisure environments, in health and rehabilitations, in professional services and in hazardous environments
- Space and Security robots
  - Concerned with the use of robots in land, sea, subsea, air, space and crisis or civil security management missions

In this thesis the main focus will be on trends in industrial and service robots market across the world and in general according to statistics industrial robotics is mature, and service robotics should drive the growth (Fig. 1.).

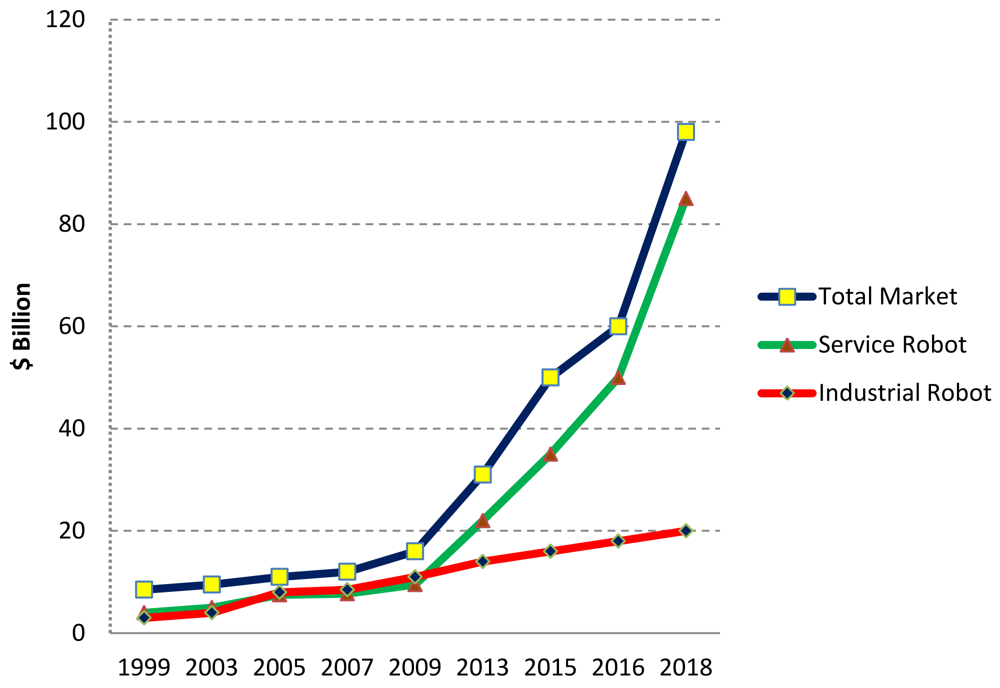

Fig. 1. Global Robotic Market Outlook (Ministry of Knowledge and Economy of South Korea, 2011)

ABI research (Solis, 2011) forecasted task robots (mower ,litter cleaning, vacuum, mop, floor cleaning robot) will be growth to 8,5 billions of US$ in 2015. The service robotics sectors is already dynamic, active in a multitude of industries, emerging in many more, likely to have a serious worldwide economic impact, and encompasses all manner of processing, service, and assistance with robots.

Service robotics stock still is outperforming NASDAQ (National Association of Securities Dealers Automated Quotations). Whereas industrial robots will have a steady need for robots, the real breakthrough and potentially disruptive technologies will be in the area of service robots (Bonnell, 2011).

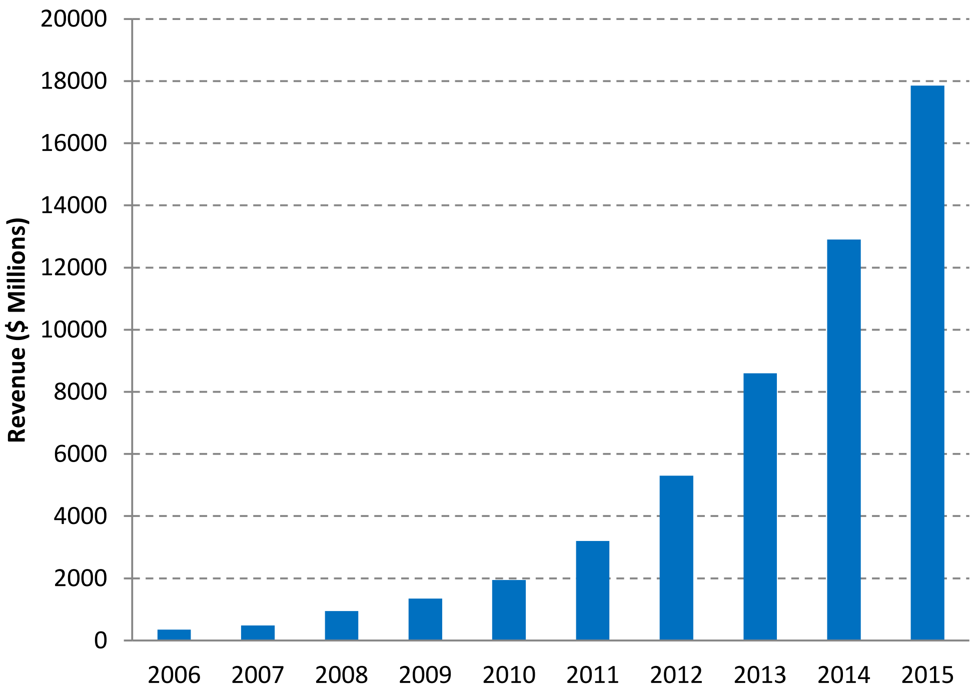

Fig. 2. Expectation of Robotic Market Growth till 2015 (Arora, ABI research, 2011)

According to ABI research approximately 18 billion US dollars revenue worldwide in 2015 on the personal robotic market will be investigated (Fig. 2.). This massive increase is due to:

- Increase of home penetration

- Multiplication of personal robot offers
- More accessible prices

3.3 Global Industrial Robots Market and Industry Demands

Low levels of economic activity has exerted a disproportionate impact on industrial production as a result of reduced manufacturing or engineering activities, which resulted in softening demand for industrial robots. One of the causalities of the recession has been the capital goods sector, which received the hardest blow from the financial hardships inflicted by the downturn. Given the widespread diffusion of industrial robots, especially assembly line robots, robot investments in large companies are already a part of the capital structure thus bringing industrial robots directly under the yoke of recession induced capital rationalization process.

Given the high sensitivity of robotics industry to the health of automotive, consumer goods, semi-conductor & electronics and rubber & plastic industries, the recent decline in new purchase orders for robot installations comes as no surprise. With most key end-use sectors collapsing like a pack of cards, the industrial robotics market witnessed broad based declines in sales, over the last two years (Global Industry Analysts, Inc., Jan. 2011).

The beleaguered automotive industry, one of the largest end-user sectors, especially played an instrumental role in dragging down growth of industrial robotics. Massive declines in new vehicle sales, continuous trimming of auto plant production capacities, plant closures, capacity idling, and reduction in automobile output, resulted in reducing the number of robotic machinery orders from the automotive industry.

However, this deterioration in growth has been largely temporary and the recession has not endangered the economic fundamentals of industrial robotics, which continues to remain firmly rooted in advantages of manufacturing, production and labor cost efficiency. The fact is mirrored by the market's sharp recovery staged in the year 2010. Key reasons fingered for the quick resurgence in spending on robotic automation is the accumulation of postponed and deferred orders, and reinvestment of manufacturers in plant renovation, and modernization, and capacity expansions. Additionally, also emerging clear over the post recession horizon is the new age of thrift, wherein the prolonged financial hardships continue to chisel the emergence of post recession cost wary end-users keen on exercising renewed focus on long-term cost savings, and benefits.

Strong increase of robot installations of about 18% to a new peak of about 139,300 units is estimated for 2011. The main impulses are coming from North America, China and other Southeast Asian countries. Investments in Japan will gain momentum as reconstruction and new projects are carried out in the coming months. Japan is likely to return at the top of the robot market in 2011 (Litzenberger, IFR Statistical Department, 2011).

As a consequence of the disaster in Japan, Japanese companies have been trying to diversify their production geographically. This will result in considerable investments in robot installations in Asian markets as well as in Europe and in North America. The robot supply to the Republic of Korea will only slightly increase after the huge investments in 2010. Robot supply to China will surge and finally at least in 2014 China will be on top of the robot markets. The robot sales in Europe will increase below average because of a rather moderate increase in investment by the western European countries (Litzenberger, IFR Statistical Department, 2011).

The robot installations in the eastern and central European countries will surge in 2011. However, it is still possible that due to a shortage of components and capacity problems a part of these expected robot installations will have to be shifted to 2012. The automotive industry is continuing to be the main driver of the growth in worldwide robot installations with investments in new technologies, further capacities and renovation of production sites. Investments of the General Industry (all other industries, except automotive) are gaining momentum. The trend towards automation which was interrupted by the economic crisis in 2008/2009 will further boost robot installations. The success story of industrial robots will continue also after 2011. Huge consumer markets are opening up in China, India, Brazil, Russia, and in Southeast Asia. All industries will increase capacities and modernize existing production sites in the years to come in these markets. The necessary increase of automation of the industrial production will continue in the United States (Litzenberger, IFR Statistical Department, 2011).

The companies are forced to make these investments in order to be competitive on the world market. Rising wages and the increasing standard of living will also push automation in still low-wage countries in Eastern and Central Europe as well as in Asia and in South America. The Middle Eastern countries are becoming new markets for automation. Apart from any economical development, the robotics industry is confronted with the modification of production processes due to the individualization of consumer products. The handling of robots has to become much easier, ever greater flexibility is necessary, and rapidity and accuracy have to be increased. The robotics industry is on track to meet these challenges.

A further increase will resume in the period between 2012 and 2014 about 6% per year on average attaining a level of about 167,000 units. In the Americas sales will be up by 31% in 2011, in Asia/Australia by 16% and in Europe by 13%. Between 2012 and 2014, robot shipments will increase by about 6% per year on average: about 6% in the Americas, about 7% in Asia/Australia, and about 4% in Europe is presented in Table 1 (IFR, industrial robot, 2011).

When comparing the distribution of multipurpose industrial robots in various countries, the robot stock, expressed in the total number of units, can sometimes be a misleading measure. In order to take into account the differences in the size of the manufacturing industry in various countries, it is preferable to use a measure of robot density.

One such measure of robot density is the number of multipurpose industrial robots per 10,000 persons employed in manufacturing industry or in the automotive industry or in the “general industry” (which is all industries excluding the automotive industry).

Table 1 Estimated Annual Shipments of Multipurpose Industrial Robots in Selected Countries-Number of Units. (IFR, industrial robot, 2011)

Country	2009	2010	2011	2014
America	**8,992**	**17,114**	**22,450**	**26,700**
North America (Canada, Mexico, USA)	8,417	16,356	21,000	24,000
Central and South America	575	758	1,450	2,700
Asia/Australia	**30,117**	**69,833**	**81,200**	**100,000**
China	5,525	14,978	19,500	32,000
India	363	776	1,000	3,000
Japan	12,767	21,903	26,000	30,000
Republic of Korea	7,839	23,508	24,500	21,000
Taiwan	1,474	3,290	3,700	4,500
Thailand	774	2,450	3,100	5,000
other Asia	1,375	2,928	3,400	4,500
Europe	**20,483**	**30,630**	**34,700**	**38,900**
France	1,450	2,049	2,400	2,800
Germany	8,507	14,000	15,500	16,500
Italy	2,883	4,517	4,600	4,900
Spain	1,348	1,897	2,100	2,400
United Kingdom	635	878	950	1,100
Central and Eastern Europe	1,448	2,507	3,700	5,100
other Europe	4,212	4,782	5,450	6,100
Africa	**196**	**259**	**400**	**500**
Total	**59,788**	**117,836**	**138,750**	**166,100**

The most automated countries in the world – include: Japan, the Republic of Korea and Germany. In 2010, these three countries had robot densities of 306, 287 and 253 respectively. While the density in Germany and the Republic of Korea increased continuously up to 2010, it was more or less stagnating in Japan between 2006 and 2009 and had a considerable decline in 2010. 9 countries of the 45 surveyed countries have a robot density between 103 (Austria) and 161 (Italy), 7 countries from 50 to 100, 5 countries from 20 to 49 and all others (21 countries) have less than 20 robots in operation per 10,000 employees in the manufacturing industry. The estimated average robot density in the world is about 50 industrial robots in operation per 10,000 employees in manufacturing industry.

The considerable high rate of automation of the automotive industry compared to all other sectors is demonstrated in the evaluation of the number of industrial robots in operation per 10,000 employees in automotive industry and in all other industries.

Japan has by far the highest robot density in the automotive industry. 1,436 industrial robots are installed per 10,000 persons employed in the automotive industry and 191 in all other industries. In Germany 1,130 robots per 10,000 employees were installed in the automotive industry. But in all other German industries the robot density is 134, which is significant compared to all the other countries.

Only Japan and the Republic of Korea had a higher rate, 191 and 215 respectively. These higher rates are mainly due to robot installations in the electronics industry. The comparatively high rate in Germany is due to a more diversified distribution of industrial robots in all industries, especially in the metal industry, the chemical industry and the food industry as well as in the electronics industry.

Regarding the robot density in the automotive industry, Italy ranked number 3 with a robot density of 1,229. In other sectors the robot density was increasing and reached 114 robots operating per 10,000 employees in 2010. In 2010, 1,112 industrial robots per 10,000 employees were installed in the automotive industry in the United States, but only 69 in all other sectors.

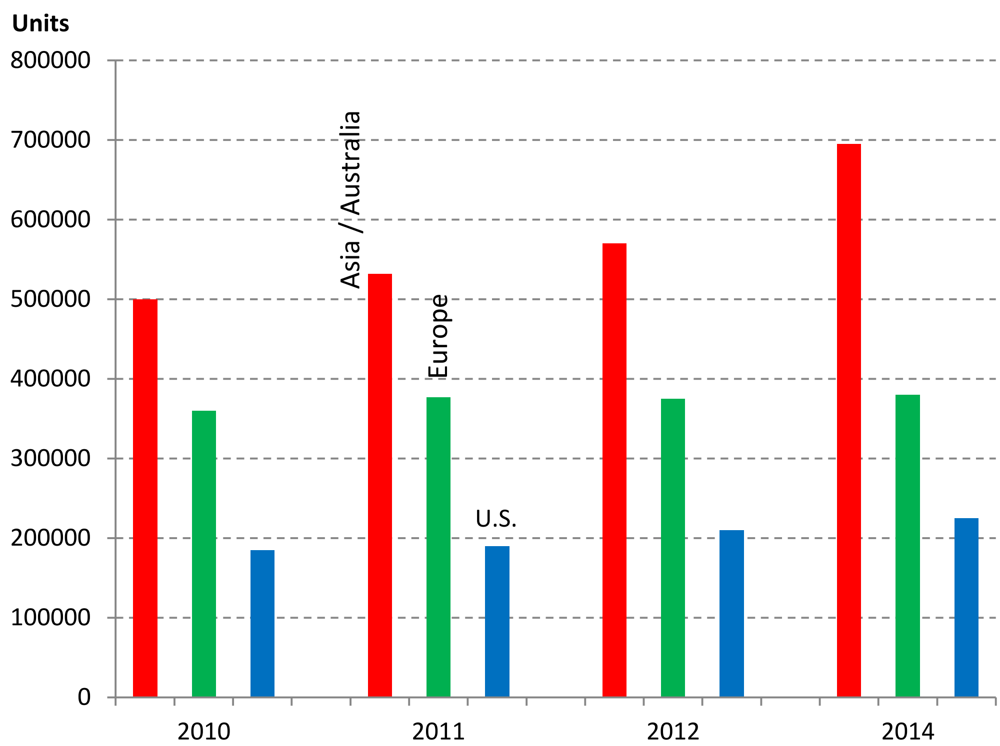

Fig. 3. Estimated Global Operational Stock of Industrial Robots 2010 and Forecast for 2011-2014 (IFR, industrial robot and forecast, 2011).

In China, the huge robot investments in the recent years resulted in a substantial increase in the robot density of the automotive industry. Between 2006 and 2010, it was up from 37 to 105 robots per 10,000 employees. Also all other sectors increased their robot density considerably from 30 to 86 during the same period. However, the potential for new installations in this market is still tremendous.

In Fig. 3. the estimated of operational stock of industrial robots on last year (2010) and forecast from 2011 till 2014 in Asia including Australia, Europe and U.S. are compared and in more details in Table 2 are described. As it presented rate of operational stock of industrial robot is increasing more sharply rather than the other part of the world.

Table 2 Estimated Operational Stock of Multipurpose Industrial Robots at Year-End in Selected Countries-Number of Units (IFR, industrial robot, 2011).

Country	*2009*	*2010*	*2011*	*2014*
America	**172,141**	**179,785**	**189,200**	**229,000**
North America (Canada,Mexico,USA)	166,183	173,174	181,300	216,600
Central and South America	5,958	6,611	7,900	12,400
Asia/Australia	**501,422**	**498,933**	**539,900**	**695,000**
China	37,312	52,290	71,200	155,600
India	4,079	4,855	5,800	13,000
Japan	332,720	285,800	276,200	262,000
Republic of Korea	79,003	101,080	123,150	169,300
Taiwan	24,365	26,896	29,800	40,400
Thailand	7,185	9,635	12,700	25,100
other Asia	16,758	18,377	21,050	29,600
Europe	**343,661**	**352,031**	**360,700**	**376,000**
France	34,099	34,495	33,800	31,400
Germany	144,133	148,195	153,100	158,300
Italy	62,242	62,378	61,800	58,400
Spain	28,781	28,868	28,900	26,800
United Kingdom	13,923	13,519	13,100	11,800
Central and Eastern Europe	11,470	13,761	17,100	28,300
other Europe	49,013	50,815	52,900	61,000
Africa	**1,973**	**2,232**	**2,600**	**3000**
Total	**1,019,197**	**1,032,981**	**1,092,400**	**166,100**

Certain risks are involved with regard to this rather optimistic forecast, i.e. weakening growth of the world economy or even a new recession caused by financial problems of major markets. This trend therefore has and will continue to witness manufacturers reevaluate investment priorities on technologies or products that help improve efficiency and reduce costs, thus benefiting the market for cost oriented industrial robotics. Revival in automotive sector, which is a major end-use market for industrial robotics, bodes well for the future of the market, as a resurgence in consumer demand for new cars, will surely encourage automotive manufacturers to adopt robots for helping them bring out more number of new car models in less time, and also be competitive in the market by ensuring sustainable production processes and sustainable products.

Advantages of automation, which hitherto was focused on and reaped by the automobile industry, will now witness other industrial sectors, such as, plastics & rubber and food and beverage handling and processing, wax in popularity as lucrative end-users of robotics on par with the automotive industry.

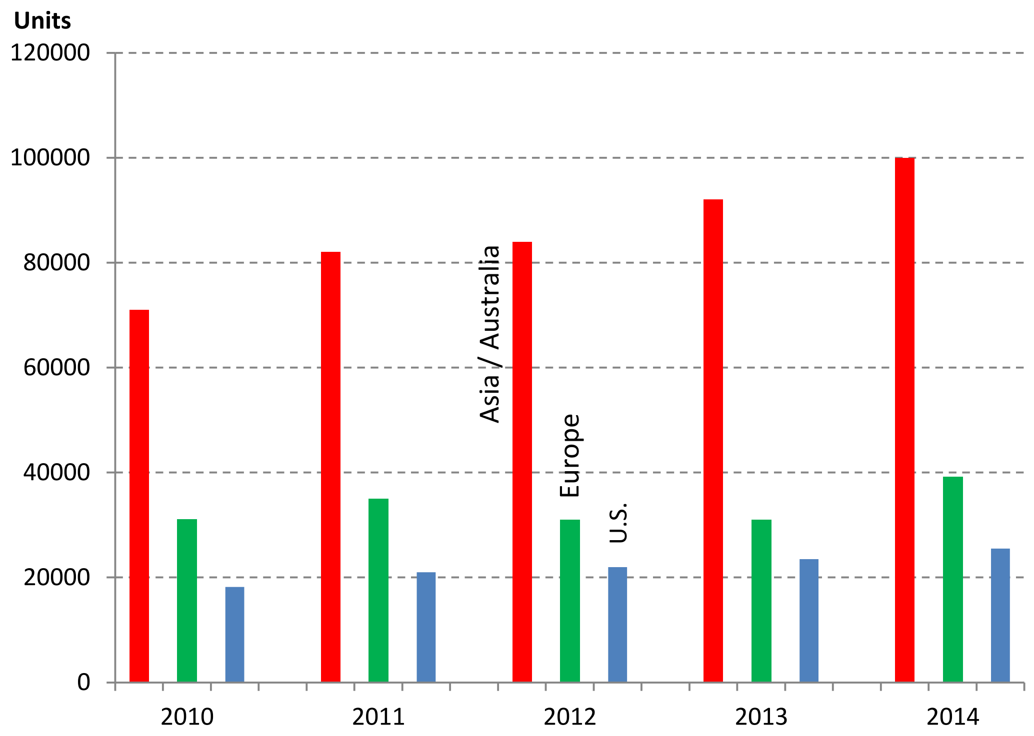

Fig. 4. Supply of Industrial Robots in 2010 and Forecast for 2011-2014 (IFR, industrial robot, 2011)

Emerging areas such as high volume toy manufacturing, medical and healthcare industries will create substantial demand for industrial robots over the next few years. The supply of industrial robots in 2010, and forecasting for 2011 till 2014 is presented (See Fig. 4.). As it clear the Asia (including Australia) has the first rank in supplying of industrial robot, and Europe and U.S. ratio is less than the half of Asia.

Additionally, new product developments, for instance the new-age industrial robots, which act as independent systems, capable of utilizing their artificial reasoning skills in performing a range of tasks independently, will drive increased adoption of industrial robots in the post recession era. Technological advancements in the field of machine vision and distribution motion control also augur well for the future of this market.

Demographic trends, such as aging population and declining birth rates in several western countries and Japan, which point towards a situation, where less number of people will enter the workforce as more number of people whom retire with time, also project extensive use of industrial robots in these nations in order to meet the demand supply gap.

As stated by the new market research report on industrial robotics, Europe continues to remain the largest regional market worldwide. Asia-Pacific is the fastest growing regional market, with volume sales of industrial robots. Growth in this market will be essentially driven by countries such as South Korea, and China, which host some of the leading electronics manufacturers in the world, thus generating substantial demand for robots capable of handling production of a range of electronic products.

Increase in outsourced manufacturing activity in low-cost destinations such as China and India, is also creating the demand for industrial robotics in the region. By End-Use, Assembly Line represents the largest application market for industrial robotics worldwide. Welding however remains a key contributor towards volume sales for industrial robots in North America and Europe.

3.4 Global Service Robot Trends & Market

Robot which operate semi or fully autonomously to perform services useful to the well-being of humans. Service robotics is usually divided in 2 main categories:

- Professional Service Robot
- Personal Service Robot

The most important trend in robotics market witnessed in the recent times has been a shift of researchers and manufacturers focus from industrial robots to service robots. The use of service robots in various applications in different industry has opened up new opportunities in the service robotics market. Service robots are being preferred over humans for dull, dirty and dangerous jobs.

The major factors driving the growth of the service robotics market are:

- Increasing aging population
- Shrinking labor market for dull and dangerous jobs
- Value enhancement by robots to suppliers and customers
- Advancement in robotic technology with continuous research and investment.

The factors that hinder the growth of the service robotics market are:

- Safety for humans
- Limited ability of robots to work in unstructured environment
- Limited ability of robots to work in network of robots, sensors and users.

Major opportunities for the service robotics market

- Untapped market of developing economies
- Labor shortage
- Application of robots in diverse industries

3.4.1 Professional Service Robots Trends

The transition of the world's developed economies towards being a service economy offers ample opportunities for growth in service robots market. Given their ability to offer a technological platform for supporting the growing needs of the professional services industry and thus triggering strong economic growth in the process, service robotics is slated to witness considerable opportunities in the years to come. Professional service robots trends include field, infrastructure, transportation, logistic, medical, and health, education, security, and surveillance, manufacturing, representation robots (Fig. 5.). Professional service robots are more expensive than personal (domestic) robots.

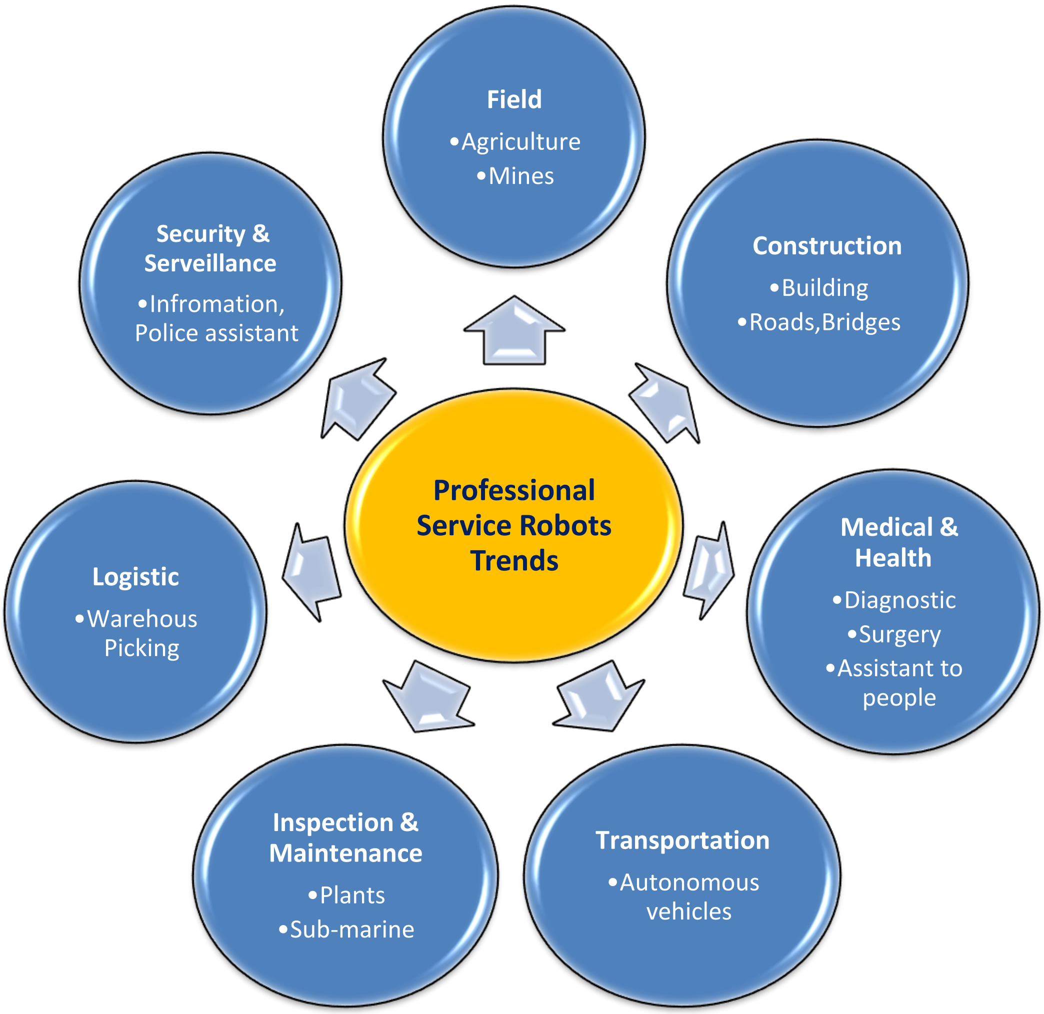

Fig. 5. Trends in Professional Service Robots

The professional use robots market makes up for the largest segment in the service robotics market, by value. On the other hand, personal use robots market represents the fastest growing segment in terms of value. Personal robots are also the largest market segment in the service robotics market, by volume.

3.4.2 Personal Service Robots Trends

Imagine a bed that could analyze your body and set into the right position of your back, a clock that would study your sleeping cycle and wake you up when it is best, a pan that could evaluate the food and set the right cooking time…

Personal service robot is one of the promising areas to which robotic technologies can be applied. One of the important aspects of such robots is the user-friendliness in communication; especially, the easiness of user's assistance to a robot is important in making the robot perform various kinds of tasks.

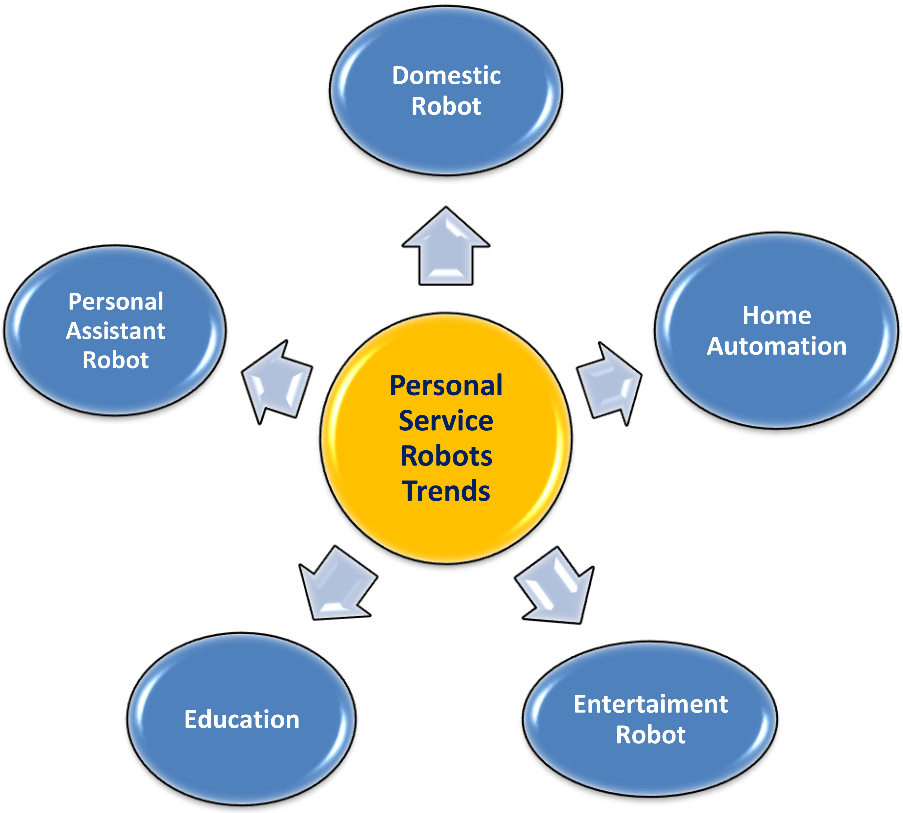

Fig. 6. Professional Service Robotic Trends

Trends in service robots include domestic robots that may perform daily chores, assistance robots (for people with disabilities or seniors), humanoid robot (robots that offers a unique research tool for understanding the human brain and body, includes a rich diversity of projects where perception, processing and action are embodied in a recognizably anthropomorphic form in order to emulate some subset of the physical, cognitive and social dimensions of the human body and experience), educational robots and robots that can serve as companies or robots for entertainment (Fig. 6.). Imagine your robotic butler do your shopping, coking your food, taking care of your children, help you in your work, and carrying for you overall well being.

3.4.2.1 Projections of Service Robots from 2011till 2014

The market for service robots is estimated to reach $21 billion by 2014. Most of the growth potential lies in the field of personal robots, defense, rescue and security robots and medical robots. The market has seen an exponential growth since 2002 however there was fall in 2009 due to the global crisis. Sales of professional service robots are forecast to increase by about 87,500 units. Therefore, more than 25,500 milking robots will be sold in the period 2011-2014. They are followed by service robots for defense applications with more than 22,600 units. This is probably a rather conservative estimate. These two service robot group make up 55% of the total forecast of service robots.

Projections for the period 2011-2014 is about 14.4 million units of service robots for personal use to be sold, it is projected that sales of all types of domestic robots (vacuum cleaning, lawn-mowing, window cleaning and other types) could reach over 9.8 million units in the period 2011-2014, with an estimated value of US$4.3 billion. Sales of all types of entertainment and leisure robots are projected at well about 4.6 million units, with a value of about $1.1 billion as illustrated in Fig. 7. (IFR Statistical Department, Service Robots, 2011)

Today, well over 200 companies worldwide offer service robotic products for professional and personal/domestic applications, with continuous growth rates of over 20% per year, however still on a not so spectacular annual turn-over level of over 2,6 billion €/year. Almost 300 product ideas, demonstrators, prototypes and products have been documented, patented and presented for almost all conceivable tasks. Nevertheless, an abundance of product opportunities await take-up by industry.

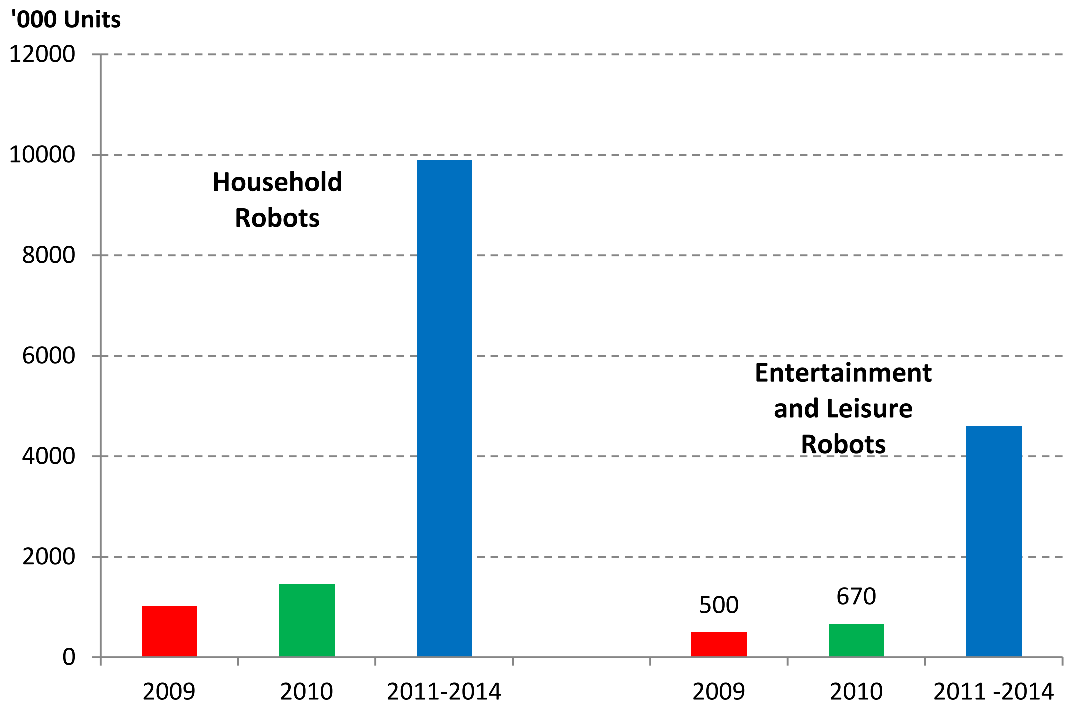

Fig. 7. Service Robots for Personnel/Domestic use, Units sales 2009 and 2010 - Forecast 2011-2014

Despite widely acknowledged market potential service robots (a robot in every household) are still challenged by providing attractive cost-for-value solutions. The conventional approach in robotics research and development towards improving the cost side of robots has been to adapt low-cost mass-market components (mainly sensors and drives) in order to exploit their performance for key robotic functions such as mobile navigation or the recognition of objects, environments or persons. This approach has produced reasonable results in selected domains, such as robots for vacuuming, lawn-mowing and pool-cleaning.

In most other cases that require complex motions, such as manipulation and grasping in everyday environments. It was felt that only radically different approaches, combining technology, product design, materials and manufacturing, would lead to attractive robotic products for large markets, thereby giving rise to major economies of scale effects the major low-cost enabler.

Cost-benefit-considerations from an end-user‘s point of view, particularly in the professional service robot domain, are the main factor for investing into these products. Therefore, in the introduction of service robot products (in their different application domain) information on their social economic should be emphasized wherever possible.

The material offered is a first step into this direction but will be continuously expanded for future issues of the report. In the text, an abundance of references are listed, where web-based links have been given priority in order to facility a quick access to additional sources. A small selection of service robotics photos have been integrated into the document.

The service robot area is taking off powered by exponential growth in computational technologies and advanced materials. Moreover, it is heading towards a public service sector with a big appetite for investments in productivity, autonomy, labor savings, cost effectiveness, quality of life improvements, self-monitoring and self-training, life condition improvements, etc. Investments will amount to hundreds of billions of dollars each year.

In this case in next chapter the trends and challenges in Asia, Europe and USA robotic market individually in various types and different applications of robots will be in more details compared and discussed.

4 GLOBAL ROBOTIC MARKET OUTLOOK

In this chapter worldwide robotic market and demand for robotic will be in 3 main categories such as Asia, Europe and U.S., separately will be investigated.

The positive predictions for 2011 were preceded by a 2010 robot sales rebound. Following devastatingly low 2009 robot sales, the international robotics industry experienced a dramatic recovery over the course of 2010. The robotics industry benefits from the increasing demand for automation especially in the Asian growing markets with China on top.

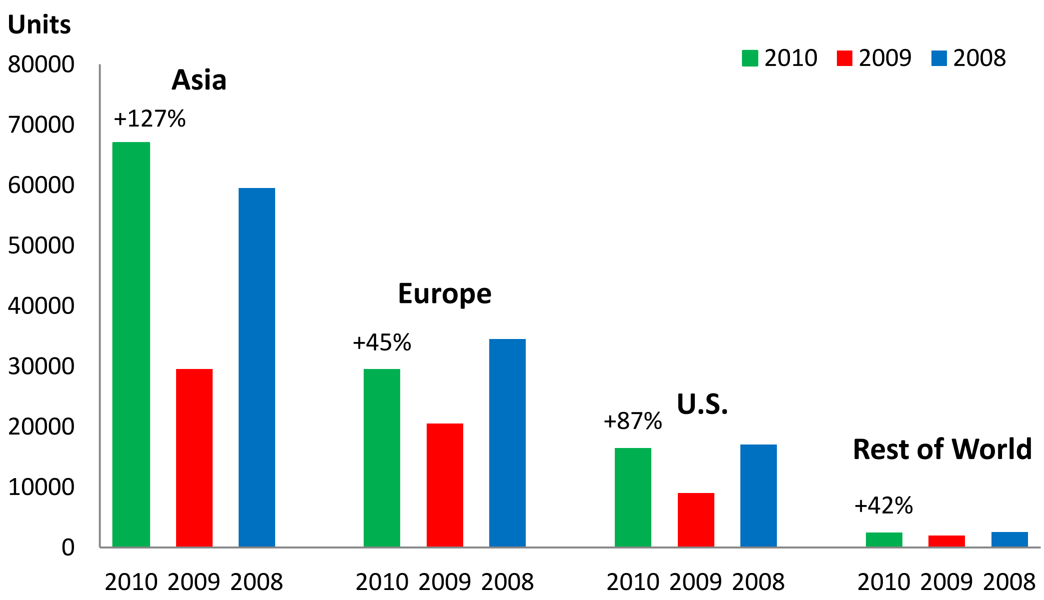

Fig. 8. Rate of Robots Units Sales in Worldwide 2008-2010 (World Robotics Unit Sales, 2011)

Various regions experienced different rates of recovery in robot sales. Asia was on top with an increase of 127% to about 67,000 units, the second highest level ever recorded. About 17,000 units were shipped to Americas, 87% more than in 2009, reaching almost the level of 2008. About 30,000 units were sold in Europe, 45% more than in 2009.

This is still about 15% lower than the peak levels of 2008 (Fig. 8.). The most dynamic markets are China, the S. Korea and the ASEAN (Association of Southeast Asian Nations) countries. Sales to these markets almost tripled. In 2010, S. Korea was on top with almost 23,000 robots sold. Japan recovered with a lower growth rate of 66% to about 21,000 units. This is followed by North America which recovered by 90% to about 16,000 units and China with almost 15,000 units sold (+170%). Germany ranked 5th with about 13,400 units sold, +57% (World Robotic Market Changes, 2011). The electronics industry, the automotive industry and the metal industry were the main drivers of the high increase of robot sales in 2010. In the following the biggest market changing is presented (See Fig. 9.).

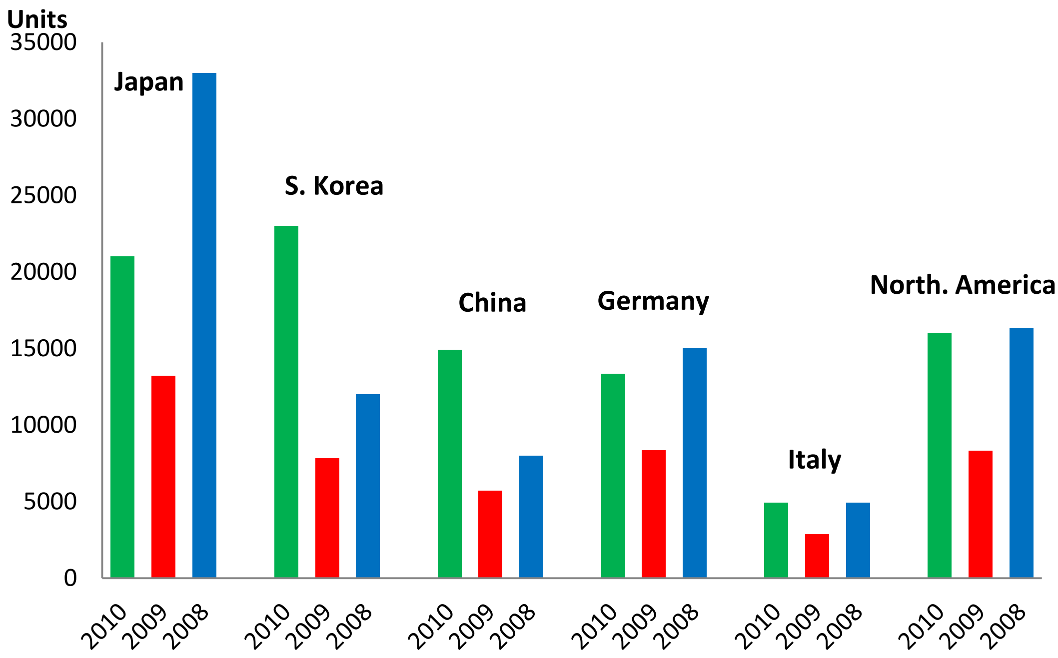

Fig. 9. Biggest Market Changes in Worldwide 2008-2010 (World Robotic Market Changes, 2011)

As it depicted in Fig. 10, the number of units sold worldwide almost doubled in 2010 compared with 2009 being lowest or worst year, since the early 90's. In 2010 overall average business is back to good years like 2007 & 2008, hence 2010, *called the year of the comeback.* On the other hand in 2011 the rate of worldwide annual supply of industrial robot will be increase 18% more than the last year. From 2012 till 2014 it is predicted that the annual supply of industrial robot will be increasing smoothly 6% per year.

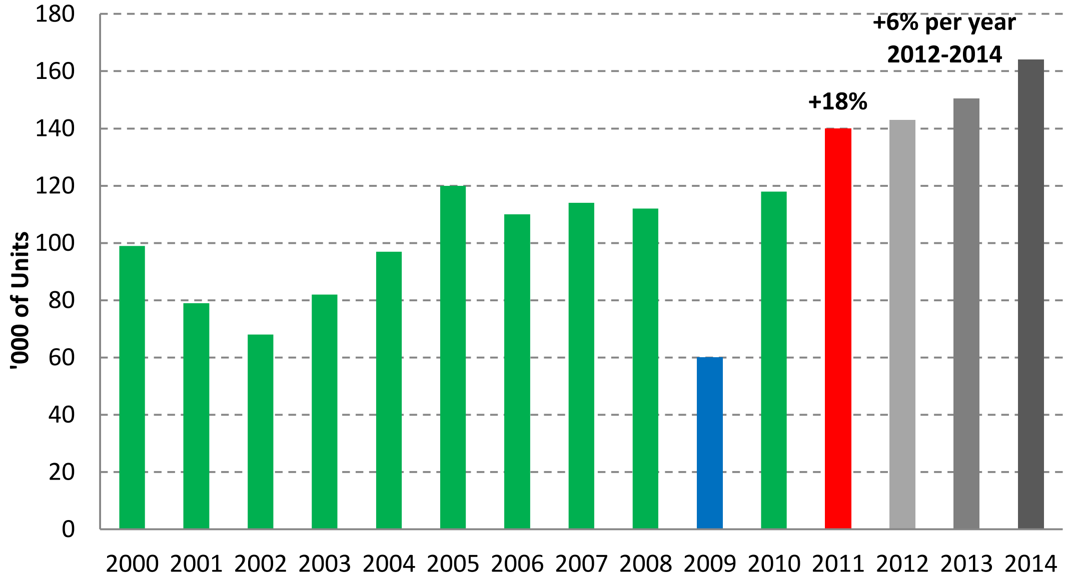

Fig. 10. Worldwide Annual Supply of Industrial Robots from 2000-2014 (IFR & World Robotic, 2011)

4.1 Worldwide Robotic Market Demand & Growth

While North America and Western Europe are experiencing tough economic times, other places in the world hold out hope for robotics. China is continuing to grow and they believe it is the end of the world when their gross domestic product growth is below nine percent. China is sitting on a lot of cash and continues to invest in robotics. China has seen a significant increase in robotics to increase productivity and quality to meet the needs of a growing middle class.

China, Brazil, India and Russia, in that order, will be the fastest areas of growth for robotics in the traditional application areas. Brazil is doing very well: Their recession was shallower and less lengthy than in the US. The Brazilian currency has stabilized, and with the weak dollar, buying automation from the US is popular now, Brazil is energy-independent, has tremendous agricultural capabilities, and is upgrading their ports. With 190 million people who consume almost three million cars a year, Brazil is poised to really explode in the automotive and durable goods markets.

The Asian market will show the largest growth over the forecast period. This sector is valued at nearly $7 billion in 2011 and is expected to increase at a 7.2% CAGR (Compound Annual Growth Rate) to reach nearly $11 billion in 2016 (Fuji-Keizai Co., Ltd., 2011).

The North American market is estimated to reach nearly $5 billion in 2011 and is expected to increase at a 2.7% CAGR to reach nearly $6 billion in 2016 (Fuji-Keizai Co., Ltd., 2011).

Manufacturing robots are driving the worldwide market since capital investment has been robust in industries where they are used most automotive and electric/electronic goods. Demand is strong in the Asia-Pacific region. Japan, the most important supplier of robotic software, hardware and peripheral equipment, is the largest market (Fig. 11.).

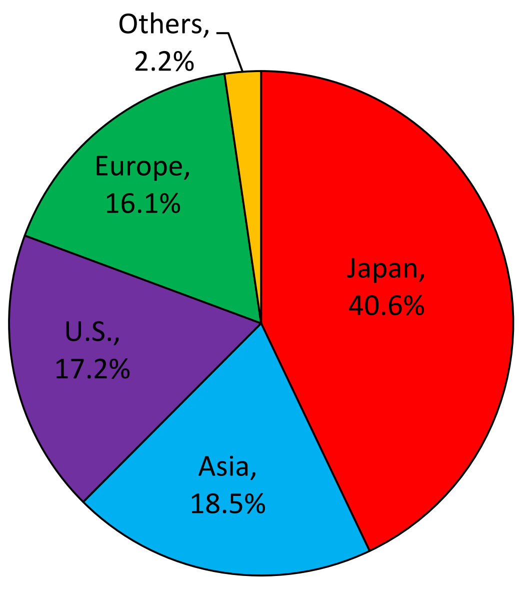

Fig. 11. Global Demand for Robots (Fuji-Keizai Co., Ltd., 2011)

Western manufacturers, led by ABB, are well respected for their expertise, but manufacturers in Taiwan, South Korea and other nations have been increasing their presence in recent years, introducing inexpensive products, and are looking to expand into North America and Europe.

4.2 Asia Robotic Market

While robot sales improved worldwide, significant increases were seen in Asia and Japan and China in particular. Other countries, such as South Korea, experienced remarkable increase. Industry sectors with the greatest amount of robot orders in 2010 included electronics, automotive vehicles, and automotive parts manufacturing. In this case the 2 main countries Japan and South Korea will be described.

4.2.1 Japanese Robotic Industry Market

While the recent earthquake and tsunami in Japan will no doubt have an impact on the robot and robotic component supply chain, a recent threat analysis from the IFR predicts that the impact will be minimal. It is important to keep in mind that the current demand for robotics remains steady. In addition, the vast majority of Japanese robot and robotic component companies are still able to manufacture and ship their products. However, some product shortages and increases in delays are expected.

FANUC is the leading manufacturer of industrial robots. FANUC has 17% of the industrial robotics market in Japan, 16% in Europe and 20% in North America. After FANUC come Kawasaki and Yasakawa. FANUC is also the leading manufacturer of CNC machines, with Siemens as its closest competitor as presented in Fig. 12. (Fuji-Keizai Co., Ltd., 2010).

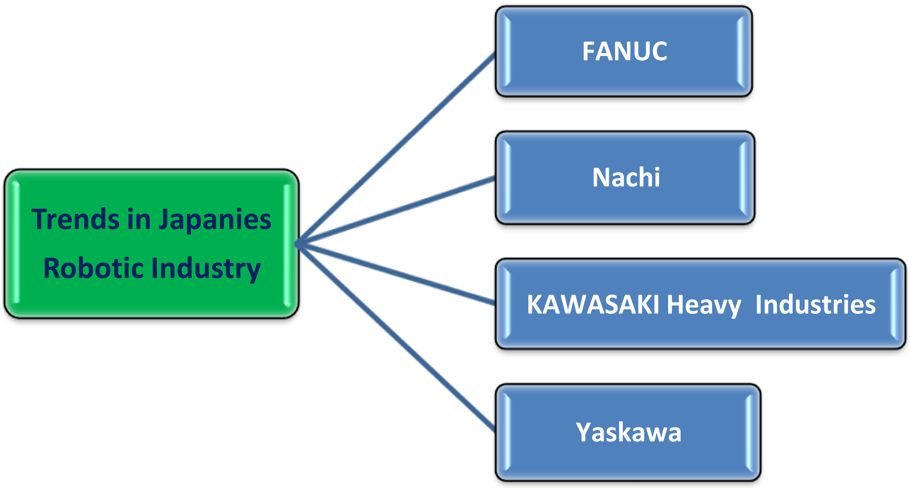

Fig. 12. Trends in Japanese Robotic Industry

- FANUC-intelligent robots: using the expertise gained in the manufacture of servo motors, numeric control equipment and other basic manufacturing equipment, FANUC began developing intelligent robots incorporating visual and tactile sensors for assembly tasks that were too difficult for previous robots. The robots are well suited to small-lot, large-variety production lines, meeting the needs of general manufacturers and FANUC's main clients, automakers. The firm teamed with Matsushita Welding Systems to establish a fully digital arc welding robot system
- Nachi-production line robots: automakers account for about 70% of Nachi's sales, but the firm wants to lower this to 60% while increasing sales to electric/electronic manufacturers. Nachi's strength is mainly large robots, but it also has alliances with Daihen for midsize robots and Denso Wave for smaller robots. About 150 of its robots are on its own production lines, with plans to increase this to about 300 machines to save labor.
- Kawasaki heavy Industries (KHI)-functional robots: KHI established its position as an expert manufacturer of industrial robots after filling an order from Kobe Steel in 2001 for new painting robots, as well as existing welding and assembly robots. First aided by automakers' expansion of capital investment in 2004, sales have grown to ¥35 billion, including robots for the

semiconductor industry. It is emphasizing the functionality of its welding, painting and transport robots to help users rationalize cost of ownership. The company has also been manufacturing in the U.S., and now plans to strengthen its networks in China and Europe to prepare for the continued overseas expansion of Japanese automakers.

- Yasakawa-service robots: applying expertise gained in producing industrial robots, Yasakawa developed the smart pal service robot to enhance its technological prowess. It plans to strengthen its European sales force to gain more orders from automakers there. In the U.S., it is pursuing orders for spot-welding robots from the Big Three automakers.

Eventually the deeper long term financial resources and strong domestic market enjoyed by the Japanese companies prevailed, their robots spread all over the globe, the companies involved in interactive robots are shown in Fig. 13.

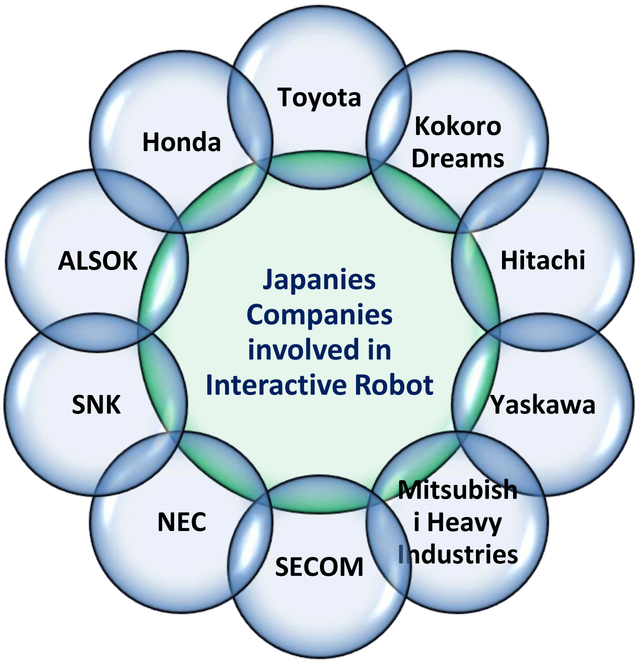

Fig. 13. Japanese Companies involved in Interactive Robotic

4.2.1.1 *Service Robotic Market Challenges in Japan*

Japan: Leader of Intelligent Service Robotics Commercialization

In the beginning, at a time when there was almost no demand for applications of any kind, prototype intelligent service robots were mostly research models developed by academic research institutions. In recent years, Japanese auto makers, especially Honda and Toyota, have expanded the scale of service robotics R&D and endeavored to achieve market objectives for product commercialization; they have also developed and been utilizing their respective ASIMO and Tour Guide Robots. ASIMO is a humanoid robot developed by Honda, which not only has biped walking and jogging capabilities, but also artificial intelligence (AI) that allows mutual interaction in response to voice and hand-gesture commands. Toyota's latest tour guide robot is capable of autonomous movement and can dodge barriers, as well as respond to voice and hand-gesture commands for interaction with visitors.

Unlike the U.S. and Europe, the service robotics industry in Japan includes big companies like Sony, Fujitsu, and Honda. The industry is driven by the perceived need for entertainment robots and domestic companions and assistants (Fig. 14.).

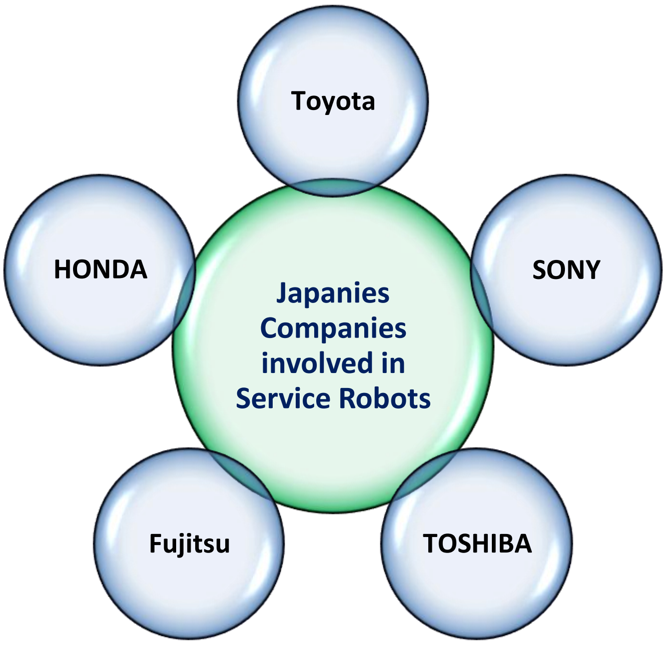

Fig. 14. Japanese Companies involved in Service Robotic Market

On the whole, the Japanese market is currently focused on industrial robots and gradually moving towards service robotics. With Japanese government agencies implementing complementary measures for industry promotion, the future development of the Japanese service robotics industry is worth watching.

4.2.2 <u>South Korea Robotic Industry Market</u>

The Korean industrial robot market ranks fourth in the world in terms of the number of robots in use. South Korea wants 100% robot market penetration by 2020

South Korea's market for robots nearly doubled last year from a year ago as demand for all types of robots, including manufacturing robots and military robots, zoomed, sales of the robot industry reached 1.93 trillion Won (US$1.82 billion) in 2010, up 97.3 percent from 980 billion won in 2009 (source: to the Ministry of Knowledge Economy of Korea, Jan, 2011). Production of the country's robot industry also increased 74.9 % on year to 1.78 trillion won. Korea is the world's No. 4 robot producer after Japan, Germany and the U.S It has been announced by the Ministry of Knowledge and Economy. South Korean government has initiated a promotional plan to intensively foster Korea’s service robot industry by making cleaning robots and educational robots the focal point (Ministry of Knowledge and Economy of Korea, Jan. 2011). A development plan has been designed to jack up Korea’s global robot market share from the current 10 percent to as much as 20 percent by 2018. As of now, Korea’s robot industry is 2.5 years behind other developed nations in terms of technology.

Therefore, the Ministry of Knowledge and Economy has ambitiously announced the service robot industry promotional plan which consists of 10 tasks to support overseas market entry, upgrade robot technologies and discover sectors with a great growth potential. The Ministry of Knowledge and Economy will pour 30 billion Won in 2011 and handpick 10 key areas to speed up overseas market entry by Korean robot makers. The promotional plan also contains market-specific export strategies to boost robot exports, for instance, surveillance robots will be mainly developed and exported to the Middle East, robot maids for the elderly to the US and the EU, and cleaning robots to China and Southeast Asian nations.

Meanwhile, to lead global standardization efforts, development of standards for the robot convergence sector will be carried through. In addition, to raising technological competitiveness, the best 8 projects will be implemented. Additionally, the six highest value-added strategic parts will be chosen to focus government support on locally producing them at an earlier date. Furthermore, the Korean robot industry’s competitiveness will be ramped up by pushing for joint R&D projects with advanced research institutions in the US, Japan and Germany.

To solidify the foundation of the robot sector’s growth, systemic efforts to nurture robot experts will be made: so called robot meister high schools will be designated and more robot R&D centers will be built at universities. What’s more, to spread knowledge on the use of robots, robot experience centers will be run on a continuing basis and best robot contests will be held. The reason why the Korean government is aggressively pressing ahead with the promotion of the service robot industry is because the global robot market, which has thus far revolved around robots designed for manufacturing, is gradually transitioning into a service robot-led one, realizing the urgency to thrash out a government-level robot promotional strategy.

4.3 Europe Robotic Market

4.3.1 <u>Europe Robotic Industry Market</u>

2010 was a very good year for the European robotic industry. According to the IFR statistical department, about 30,000 industrial robots were sold in Europe, 45% more than in 2009. This is still about 15% lower than the peak levels of 2007 and 2008 as already mentioned, but Europe is catching up. Europe has a global industrial robotics market share of approximately 30 percent. In 2010 more than 115,000 industrial robots were sold worldwide (Litzenberger, IFR Statistical Department, 2011).

The automotive industry is going to broaden its product portfolio which will require new manufacturing lines. The application of robots in other industries, i.e. the chemical, electronics, food and mechanical engineering industries will further increase. Growing demand in alternative energy sources and an increased willingness to invest within this area is also predictable which will likely increase the rate of robot installations, e.g. in the production of solar cells and wind turbines. Improvements in safety, flexibility and usability of robots will further facilitate access to new markets.

Germany, the largest of the 26 EU economies, offers profitable market opportunities for producers of innovative automation technology and peripheral equipment. The German automation sector is highly international with exports amounting to 80%, and imports at 67%. Germany produces 14% of the global automation technology. Due to Germany's central location in Europe, major European distributors of automation are operating out of Germany to supply the neighboring European markets.

Despite decreasing demand for robots in the European automotive industry, the European robotics market grew by 11%. The good results were due to the upswing in the metal processing and chemical industries, offsetting the 14% order decline in the automotive industry. Major European suppliers of robots are: KUKA Roboter GmbH, MOTOMAN, FANUC Robotics, ABB and Reis Robotics; in the servicing and electronics fields: Philips and Electrolux as well as Safran, EADS, Thales and Finmeccanica, which are mostly OEMs or system providers for robotics (Simon, 2011).

FANUC Robotics is just one example of how important the European Market is to robot suppliers. FANUC continues to invest heavily in building a strong infrastructure in Western and Eastern Europe. The building of a new EUR 11 million facility near Stuttgart is aimed at meeting the needs of the German Market.

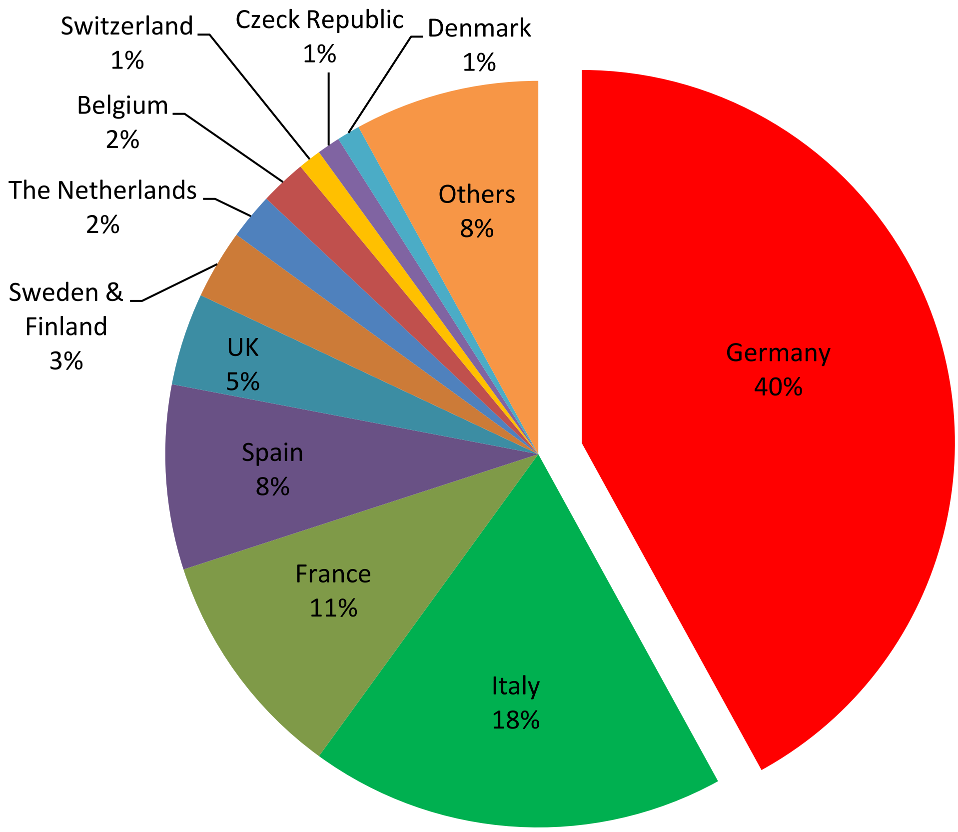

Fig. 15. Industrial Robot in Europe is dominated by Germany (Simon, 2011)

Germany is by far the largest market for multipurpose industrial robots in Europe followed by Italy with about half the size, and then France, Spain, UK and Sweden as illustrated in Fig. 15. Germany also is the country with the highest robot density in Europe: 171 robots are used per 10,000 employees in the German manufacturing industry.

According to the International Federation of Robotics (IFR, http://www.ifr.org/) based in Paris, France, best market prospects globally are in the following application areas: Underwater systems, defense, rescue and security applications, laboratory robots, professional cleaning robots, medical robots, and mobile robot platforms for multiple uses. The European robotics industry and the EU have recently agreed on a special i2010 initiative, to foster European robotics technology.

In October 2007, the European Robotics Platform (EUROP) was launched to secure Europe's leading position in robotics, and to encourage and support new companies and supply networks to meet new technological needs.

Part of EUROP (http://www.robotics-platform.eu.com) is an end-user forum encompassing representatives from industrial sectors that are major users of robotics technologies (aerospace, automotive, food and security applications). This forum is expected to state expectations, requirements, and validation principles. Working groups are set up, as needed; to focus on specific pre-defined tasks, either permanently or on an ad-hoc temporary basis.

4.3.1.1 European Industrial Robotic Market

ABB and Kuka are the two big manufacturers of industrial robots in Europe. Over 50% of ABB is focused on automation products and industrial robots are a big part of their manufacturing automation with annual revenue of $1.5B. ABB spends 5% of their revenues on R&D, with research centers all over the world. As in the automotive and other businesses, European companies outsource the manufacture of components (motors, sensors), unlike Japanese companies, which emphasize vertical integration. (Simon, 2011) It is accepted by industry to improve factory quality, performance and efficiency, robotics has for at least three decades been a key technology in engineering industries (automotive, electronics, etc.) for increasing industrial productivity and for competitive manufacturing.

After decades of hype and disappointment, robots are at last moving out of the shop-floor to find their way into a range of new markets that promise to dramatically expand the robotics market and bring social and economic benefits to a greater range of peoples' lives. In industrial robotics, where Europe has one of the leading positions worldwide in both the production and usage of manufacturing based systems, advances in robotics technologies are allowing them to be applied in new, manpower-intensive areas such as food production, aircraft assembly and recycling of goods. As technology further develops, we will soon see the teaming of workers with robots so that the resulting networked systems become more capable and agile. Robots will thus become workers' assistants and collaborators in all areas of production, providing more flexible approaches to manufacturing and assembly and bringing to these industries the benefits of increased productivity and quality, enhanced health and safety.

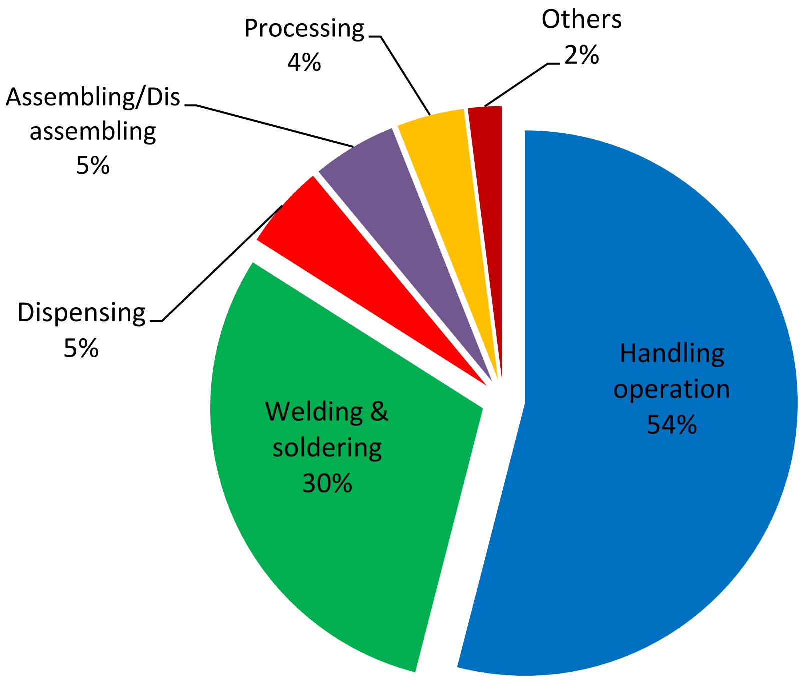

Fig. 16. Industrial Robot Tasks in Europe (Simon, 2011)

From the current trends it is evident that the operation of robots will increasingly depend on information generated by sensors, worker instructions or Computer Aided Design (CAD) product data. Thus it can be expected that manufacturing competence will be further concentrated on robot systems as a key component in the digital factory of the future. Industrial robotic in Europe is mainly for Handling and welding (See Fig. 16.)

4.3.1.2 *European Service Robot Challenges*

The European vision for future service robotics is that of robots empowering European citizens. The basis of this empowerment is that robots work with people rather than away from people; and, that robots interact with people and with each other and evolve, learn and adapt their behavior to the requirements of the task they are given and the environment they are in. Moreover, with the growing emergence of ubiquitous computing and communication environments, robots will be able to call upon an unlimited knowledge base and coordinate their activities with other devices and systems.

Further, the growing spread of ubiquitous computing will lead to robot technologies being embedded into ubiquitous ICT (Information Communication Technology) networks to become the agents of physical action, resulting in the active home, office and public environment. These new robot technologies represent a hope for a most convenient world in Europe and worldwide, enabling greater social inclusion and helping meet the challenges of the EU's graying population.

Personal assistant robots will enable a greater proportion of the population to live independently in their own homes and require less hospital or care-home based support. However, these significant social benefits should not overshadow the significant commercial opportunities for professional, personal and domestic robots. These will be very large markets and a very large worldwide supply network will develop in the provision of robotic products and support services, e.g. third party upgrades of software and / or hardware.

Europe has the necessary ingredients to meet successfully its ambitions in creating a world leading European service robotics industry, by bringing together the main industrial and academic robotic players around such a European initiative.

Europe has strong brand names in white goods and domestic services and many big companies are ready to play a very active role in the future market of service robotics. More than 100 high tech SMEs (small and medium-sized enterprises) have been created in Europe the last 5 years, bringing many new innovative solutions in the service robotics market. Europe has also several world leading academic teams in robotics research, with more than 200 universities and research institutes offering education and research in robotics, and thus creating an unparalleled basis in qualification and knowledge.

SMEs and research labs have the capacity to develop the missing robotic technology and final users begin to be convinced of the interest of robotics in everyday life. What is missing is organization of cooperation between the actors, investment to build the first products, standardization to turn competition between actors into general profit. When Japan or Korea decided to build a humanoid robot, they concentrated the efforts of their research labs and companies towards this goal. Europe has to focus its development in a same way on some well chosen specific objectives.

4.4 U.S. Robotic Industry

The U.S. robotics industry is at a disadvantage in funding for Research and Development (R&D). U.S. industry investment in R&D, an average of over nine percent of sales, is comparable with percentage investment by foreign industry. However, in aggregate dollars, it is dwarfed by foreign investment and inadequate to undertake all the projects needed to maintain competitiveness. It is at a further disadvantage compared to Japanese and Western European robotics industries which have received substantial government assistance.

In the United States, the largest amount of government assistance in robots supports R&D for often unique space and military projects which, while important in their own right, have little direct commercial application. It is estimated less than five percent of the world's total commercially related R&D in robots is funded in the United States. But as already mentioned in this thesis the main focus is on industrial and service robotic challenges and market. Strategic miscalculations have hurt the development of the U.S. robot industry. Early U.S.-produced robots were often too complicated, with unrealistically high productivity gains expected from them, causing major U.S. end-users to shift to foreign suppliers. One major user-turned-producer pursued hydraulic robots when the market moved decisively to electric robots.

4.4.1 U.S. Industrial Robot Market Challenges

As mentioned in this chapter already most of the industrial robotics industry is based in Japan and Europe. Despite of this fact it is interesting to know that the first industrial robots were manufactured in the U.S. At one time, General Motors, Cincinnati Milacron, Westinghouse and General Electric made robots. Now, only Adept, a San Jose-based company, makes industrial robots in the U.S. Meanwhile robotics is critical to U.S. national security. Robotics was identified by the 1990 Department of Defense Critical Technologies Plan as vital to long-term U.S. defense capabilities.

Robotics is incorporated in current weapons systems and will play a larger role in future systems. While defense and commercial development follow largely separate paths, a strong domestic industry is essential to maintaining U.S. involvement in the continuing overall development of robotics technology. But the United States is nearly out of the industrial robot business. A major reason has been the slow development of the factory automation market in the United States. Currently, only a few small firms exist on the edges of robotics technology surviving in application-specific niches. Most produce accessories, peripherals or sensors for end-effectors that are added to imported robot arms and bodies. Many industry observers believe it is too late to restore a viable domestic industry.

4.4.2 Trends and Investments in U.S. Service Robotic Market

Leadership of the larger and faster-growing market for service robots, a sector IFR pegs at $13 billion worldwide, is up for grabs. This business encompasses robotic applications for industries such as defense, space, health care, business logistics, and consumer products, among other markets. And U.S. companies clustered in Boston, Pittsburgh, and Silicon Valley are very much in contention. There are a number of small companies developing service robots in the U.S., iRobot and Mobile Robotics, companies in New England, are pioneering new technologies. We are world leaders in service robots," says Colin Angle, chief executive officer of Bedford (Mass.)-based iRobot, which makes the Roomba and Scooba floor cleaning machines and the PackBot, a robot that can search caves and help with bomb-disposal missions (IFR, Statistical Department, 2011).

The United States puts more emphasis on AI and control technology R&D. US manufacturers and academic institutions have all been endeavoring to develop AI robots, launching products such as the Davensi robotics system for surgical operations, tour guide robots, and the Roomba. The industry trend shows that the US is manufacturing robotic components for diversified uses, and is involved in the establishment of the robotics value chain. For example, the iRobot company's release of a series of home robots, including the first-through fourth-generation Roomba robot vacuum cleaner, has made "home rotobotization" a hot topic.

At the same time, the big three vendors (Google, Intel and Microsoft) have announced a joint-venture robotics research project to provide funding for researchers at Carnegie Mellon University for a series of Qwerkbot robots which can be connected to the Internet and can be assembled using over-the-counter parts. With the joint promotion of technological advancements and market demand, robotics has become yet another blue-sea market for businesses. Education, entertainment, and service robots are especially poised to become the most competitive products in the service robotics market (Bremner, 2011).

Big defense budgets during the 2000s financed the deployment of thousands of robots, including unmanned aerial and underwater vehicles, to Iraq and Afghanistan and helped revive the industry. (The Roomba is derived from iRobot research in mine-detection bots financed by the military.) The Pentagon's fascination with robots hasn't waned.

In 2010, the Defense Advanced Research Projects Agency (Darpa) budgeted $23 million on three in-house programs heavily focused on robotics, funding projects including the development of a creepy-looking quadrupedal pack robot from Boston Dynamics called the Legged Squad Support System (LS3). Darpa awarded the

Waltham (Mass.) company $1.6 million to begin work on a prototype human-like robot called the Atlas that can walk upright and use its hands for balance to squeeze through narrow passages on surveillance or emergency rescue missions (Bremner, 2011).

The absence of a domestic robotics industry will slow future applications development. The absence of U.S. robotics producers will force U.S. factory systems integrators, both commercial and defense, to focus automation alternatives on the available foreign made robots, rather than develop new robots to provide optimal solutions for U.S. manufacturers. In many cases, this will bring less than desired results, especially for small- and medium-sized firms that lack the leverage of larger firms. Also, foreign sales and support offices are no substitute for the complete technical support a domestic robotics manufacturer could provide.

5 TRENDS IN HUMANOID ROBOT MARKET AND NEW OPPROTUNITIES IN ROBOTIC

5.1 Humanoid Robot Market and Challenges

The research on humanoid robots has gained a particular interest in this new phase as humanoids tend to change the concept of the robot. In the past, robots were confined to the industry carrying out such jobs as welding, and parts-assembly (automobile and electronic devices) in that the objectives, specification and optimal design parameters were clearly defined with concern to the economic aspects, productivity and efficiency. As the economical paradigm is changing from mass production to small quantity batch production, people’s concept of the robot has been gradually diverging. By today, it has come to a situation, where the robot should be able to perform a wide variety of functions that helps people in their daily life.

Hence on the tree of robotic life, humanlike robots play a particularly valuable role. It makes sense. Humans are brilliant, beautiful, compassionate, loveable, and capable of love, so why shouldn’t we aspire to make robots humanlike in these ways? Don’t we want robots to have such marvelous capabilities as love, compassion, and genius? Even though the market size is still small at this moment, applied fields of robots are gradually spreading from the manufacturing industry to the others as one of the important components to support an aging society.

For this purpose, the research on Human Robot Interaction (HRI) has been an emerging topic of interest for both basic research and customer application. More and more group worldwide work on issues like bipedal locomotion, dexterous manipulation, audio-visual perception, human-robot interaction, adaptive control, and learning, targeted for the application in humanoid robots.

These efforts are motivated by the vision to create a new kind of tool: robots that work in close cooperation with humans in the same environment that we designed to suit our needs. While highly specialized industrial robots are successfully employed in industrial mass production, these new applications require a different approach, general purpose humanoid robots.

The human body is well suited for acting in our everyday environments. Stairs, door handles, tools, and so on are designed to be used by humans. A robot with a human-like body can take advantage of these human-centered designs.

The new applications will require social interaction between humans and robots. If a robot is able to analyze and synthesize speech, eye movements, mimics, gestures, and body language, it will be capable of intuitive communication with humans. Most of these modalities require a human-like body plan. A human-like action repertoire also facilitates the programming of the robots by demonstration and the learning of new skills by imitation of humans, because there is a one to one mapping of human actions to robot actions. Certainly robots don't have these capacities yet, but only by striving towards such goals do we stand a chance of achieving them. In designing human-inspired robotics, we hold our machines to the highest standards we know humanlike robots being the apex of Bioinspired engineering.

In the process, humanoid robots result in good science. They push the boundaries of biology, cognitive science, and engineering, generating a mountain of scientific publications in many fields related to humanoid robotics, including: computational neuroscience, A.I., speech recognition, compliant grasping and manipulation, cognitive robotics, robotic navigation, perception, and the integration of these amazing technologies within total humanoids. This integrative approach mirrors recent progress in systems biology, and in this way humanoid robotics can be considered a kind of meta-biology. They cross-pollinate among the sciences, and represent a subject of scientific inquiry themselves

Last, but not least, humanoid robots are used as a tool to understand human intelligence. In the same way Biomimetic robots have been built to understand certain aspects of animal intelligence, humanoid robots can be used to test models of aspects of human intelligence. Looking forward, we can find an additional moral prerogative in building robots in our image. Simply put: if we do not humanize our intelligent machines, then they may eventually be dangerous.

To be safe when they "awaken", I mean gain creative, free, adaptive general intelligence, and then machines must attain deep understanding and compassion towards people. They must appreciate our values, be our friends, and express their feelings in ways that we can understand. Only if they have humanlike character, can there be cooperation and peace with such machines. It is not too early to prepare for this eventuality. That day when machines become truly smart, it will be too late to ask the machines to suddenly adopt our values. Now is the time to start raising robots to be kind, loving, and giving members of our human family.

5.1.1 Latest Humanoid Robot Rise

Japan has long held world dominance when it comes to full-body walking humanoid robots. There's the pioneering Waseda robots, the impressive HRP series, the diminutive but nimble Sony Qrio and Toyota Partner robots, and of course, the country's most famous emissary: the charismatic, child-size, astronaut-like Honda ASIMO, which ambles, runs, and climbs stairs with (almost) perfect precision. Until recently, only South Korea with its Hubo and Mahru robots had demonstrated humanoids with legs as impressive as those of their Japanese counterparts. Now other countries are trying to catch up.

But should all of them have legs? So if we want robots to operate in our homes and offices, where there are stairs, uneven surfaces, and shaggy rugs, we need legs. The second part of the answer is that by building walking humanoids we can better understand how *humans* walk, balance, and move our bodies to do things like pirouette on a toe or perform incredible kicks.

After hearing their answer, my next question to the humanoid builder is, and why is it so hard to create full-body walking humanoids? Researchers have been working on this for over three decades and it seems we're still taking, well, baby steps. When can we expect a quantum leap in humanoid legged locomotion?

Latest humanoid robots rise are depicted in Fig. 17. (IEEE Spectrum, 2010) , from left to right ***ROMEO*** is French humanoid robot 1.4 meter-tall is able to walk through a home, fetching food from the kitchen, taking out the garbage, and acting as a loyal companion who helps entertain its owners and keep tabs on their health.

The strongest humanoid in the world is ***Reem-B***, from Barcelona that can carry a 12-kg. payload.

JUSTIN from Institute of Robotics and Mechatronic at the German Aerospace Center, Its lightweight, strangely shaped arms are amazingly dexterous, and the German researchers are consistently pushing the envelope in terms of hardware and software design.

CHARLI is the first autonomous, full-size walking humanoid robot built in the United States, according to Virginia Tech roboticist Dennis Hong. Hong loves creating acronyms for his robots. CHARLI stands for Cognitive Humanoid Autonomous Robot with Learning Intelligence.

SURENA II The 1.45-meter-high robot was developed to help researchers explore aspects of bipedal locomotion, in Tehran University, Iran. It might be a slow walker, but it has its tricks: It can bow, stand on one leg, and dance.

Fig. 17. Trends in Humanoid Robot (Guizzo, IEEE Spectrum, 2010)

For now, let's just say there is a preferred walking control scheme, but some researchers are betting on competing approaches, and that although dc motors are the preferred actuators, some groups are seeking alternatives such as compact, powerful linear actuators.

Humanoids may prove to be the completely ideal robot design to interact with people. After all, humans tend to naturally interact with other human-like entities; the interface is hardwired in our brains. Their bodies will allow them to seamlessly blend into environments already designed for humans. In the future, technology will adapt to us. Undoubtedly, humanoids will change the way we interact with machines and will impact how we interact with and understand each other. But the most important research area in future will be on cost oriented humanoid robot.

5.1.2 Application Domains

Because the capabilities of humanoid robots are rather limited, there are few real-world applications for them so far. The most visible use of humanoid robots is technology demonstration.

- Technology Demonstration
- Space Missions
- Manufacturing and Production Line
- Household
- Robot Competitions

The continuous improvements of computer vision and speech recognition systems will make it easier to use humanoid robots in unmodified environments. Advances are also to be expected from the mechanical side. Multiple research groups develop muscle like actuators with controllable stiffness. Such compliant actuation will significantly contribute to the safe operation of robots in the close vicinity of humans. Compliance also leads to control schemes that support the dynamics of the body instead of imposing inefficient trajectories on it.

Insights from biophysics and neuroscience also give ideas for robust control strategies, which degrade gracefully in case of disturbances or component failure. In general, research on humanoid robots strengthens the respect for the biological model, the human. Much remains to be learned from it in areas like perception, mechanics, and control.

Fig. 18. ASIMO helping a child learn to set a table (Okita, 2010)

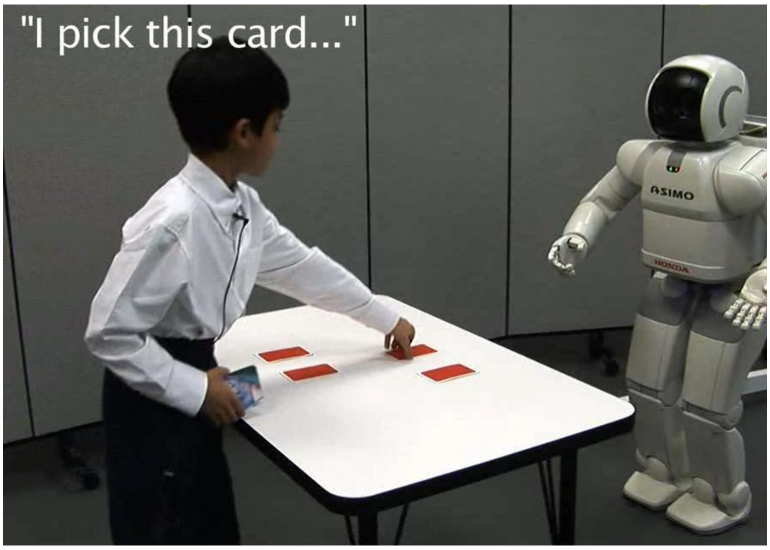

Fig. 19. Memory Game (Okita, 2010)

Two remaining issues could hinder the widespread application of humanoid robots: costs and system complexity. Here, the toy industry played a pioneer role with the introduction of simple, inexpensive humanoid robots. The low costs needed for the toy market are possible because of the high volumes. Children are growing up now with robotic companions. As personal robots mature, they will meet prepared users (See Fig. 18. and Fig. 19.).

These physical capabilities are directly related to both the core hardware components technologies such as actuation, sensing, material and structures and the solutions adopted at the mechanism level. Recent advances in all these component technologies have provided a solid foundation for the development of sophisticated humanoid body-ware components leading to new advanced humanoid platforms with improved physical performance.

This special issue will address the latest advances, related works and future research directions in the field of humanoid robot body-ware design and development. Global trends for this special issue will be focused on the following main topics in future:

Mechatronic realization of humanoid robots including implementations of:

- Full body platforms
- Upper body assemblies (Arm, hand and Head)
- Lower body systems (Legs and foot mechanisms)

❖ Contributions in the above areas are expected to highlight novelties in one or more of the following core humanoid body ware component technologies:

- Body Mechanisms and structures
- Actuation and sensing system
- Materials
- Power autonomy

5.2 New Opportunities, New Jobs?

Business and social issues could still slow the robot revolution, and technological hurdles remain in creating the next generation of autonomous, versatile, multitasking robots that most people imagine when they think of a robot. But the simple task-specific machines already making inroads illustrate how robots are beginning to change the way many of us work and live.

Japan and South Korea have both formally endorsed robot technology as a national priority and necessity, and put billions of dollars in research funding behind the drive. Inspection is another area of factory operations in which the utilization of robots is growing. In a typical inspection job, the robot positions a sensor with respect to the work part and determines whether the part is consistent with the quality specifications. While many different types of humanoids are being developed in research laboratories around the world, several robots have already made their public debut. But, it's a recent phenomenon.

The governments of Japan and South Korea have both formally endorsed robot technology as a national priority and necessity, and put billions of dollars in research funding behind the drive.

The South Korean program falls under the Ministry of the Knowledge Economy, which oversees economic growth and ensures an educated workforce. The European Union and individual European governments are beginning to see the demographic need for robots.

Robots are now reaching sufficient numbers in some areas to begin changing the way many of us live and work. There's no doubt that robots can do the heavy lifting for heavy industry they can build cars, cap deep water oil wells, even explore Mars. But the real growth in robotics will be in the consumer market. Service robots the artificially intelligent machines that can clean your house, mow your lawn, and teach your children in a classroom setting are the next challenge and opportunity for the economy.

Robotics and unmanned systems have the potential to extend human reach and expand human capacity in a variety of industries, including manufacturing, defense and security, healthcare, transportation, agriculture and natural resource management. Meanwhile, robots are already at work addressing a number of our nation's most critical needs, including reenergizing the U.S. manufacturing base, protecting citizens and soldiers, preserving our environment, making surgery less invasive, exciting kids about math and science, and enabling people with disabilities to lead normal, productive lives.

There are now plenty of robots doing manual work on factory assembly lines, but those machines follow a script and can't learn to adapt to new situations,

For example, U.S. doctors are currently utilizing sophisticated robotic devices to perform complex surgery using a minimally invasive approach, leading to a lower risk of infection, quicker recovery times and a shorter hospital stay. Investing in robotics is more than just money for research and development, it is a vehicle to transform human lives and revitalize the global economy.

The nation's robotics community is collectively poised to advance the technology and at the same time accelerate the transition of these technologies from the lab into the market. A number of recent man-made and natural disasters have further exemplified the new and emerging uses for robotics and unmanned systems. In the aftermath of Japan's devastating earthquake and tsunami, robotic systems were used to inspect the damage at its Fukushima plant, a task too dangerous for humans.

In the wake of the deep water horizon explosion, unmanned underwater vehicles were deployed to contain the flow of oil into the Gulf of Mexico. Other unmanned systems have been deployed nationally to survey and help in search and rescue and control situations such as the Red River flood in North Dakota and the Southwest wildfires. Every day, robots and unmanned systems serve as eyes in the sky and perform dangerous tasks for our troops overseas, providing an extra level of protection in hostile and dangerous environments.

In fact, the vast majority of robotics and unmanned systems innovation is happening in nascent small businesses the backbone of our economy. Federal investments in robotics and unmanned systems can ensure these companies grow, thrive, and spur our economic recovery. If we want to end the talk of a 'jobless recovery,' increasing our national investments in robotics and create millions of high-paying jobs in the process is the key. But this question comes to mind that how it is possible?

By developing improved robotics technology that can be applied to reviving our manufacturing industries, protecting the environment, reducing our dependence on foreign oil and helping provide quality care for our growing elderly population. But as graduate and fan of robotic in my opinion robotics leads to numerous new technologies, opens new markets, creates jobs, and improves all of our lives. As men and women look for better ways to accomplish their jobs, robotics and Mechatronic systems will be at the forefront as applications to use them continue to increase. On the other hand it improves our quality of life by revolutionizing health care and medicine, and makes our planet safer with the development of robots for defense, security and emergency response.

6 SUMMARY AND FUTURE VISION

The robotics industry, while in development for half a century, is still relatively in its infancy and faces a number of challenges in the years ahead. Besides the technological and cultural hurdles to overcome, questions remain unanswered regarding their economic and environmental impacts as well as the ethical issues of human and robot interaction. What is obvious is that robots, whatever form they take, will increasingly play a role in societies around the world and that the ecosystem of services and capabilities will offer increasing opportunities for designers in the years to come.

Today's market is not fully mature, as information technology advances, robots and other forms of automation will ultimately result in significant unemployment as machines and software begin to match and exceed the capability of workers to perform most routine jobs. As robotics and artificial intelligence develop further, even many skilled jobs may be threatened. Technologies such as machine learning may ultimately allow computers to do many knowledge-based jobs that require significant education. This may result in substantial unemployment at all skill levels, stagnant or falling wages for most workers, and increased concentration of income and wealth as the owners of capital capture an ever larger fraction of the economy. This in turn could lead to depressed consumer spending and economic growth as the bulk of the population lacks sufficient discretionary income to purchase the products and services produced by the economy.

There are main 10 top reasons for investments in robotic market as presented in Fig. 20. But what are the benefits from using intelligent robots? Robots can do many tasks now. However, the tasks that cannot be easily done today are often characterized by a variable knowledge of the environment. Location, size, orientation, shape of the work piece as well as of the robot must be known accurately to perform a task. Obstacles in the motion path, unusual events, breakage of tools, also create environmental uncertainty. Greater use of sensors and more intelligence should lead to a reduction of this uncertainty and because the machines can work 24 hours a day, should also lead to higher productivity. More intelligence could also lead to faster, easier setups and reduced cycle times. More intelligence should also lead to faster diagnosis of problems and better maintenance for the systems. Finally, there is the fact that to remain internationally competitive, the best technology usage is required. Waste of human or material resources is too expensive for industry and for society. It is said that as manufacturing goes so does the quality of life.

Fig. 20. Top Reason of Investment in Robotic Market

The future for robots is bright. But, how will robots affect future generations? Sometimes you can get ideas for the future by looking into the past and thinking about the changes we've seen as a result of other great inventions, like the cotton gin, airplane or Internet. Perhaps one day we will have true robotic "helpers" that guide the blind, assist the elderly. Maybe they'll be modular devices that can switch from lawn mower to vacuum cleaner, to dish washer and window washer.

The trends in cost oriented autonomous robot market and challenges and demands of the robot industry in Japan (has more robots in use than the rest of the world), Korea, Germany and in the world is compared and evaluated. As it can be seen from existing projection of future market trend and the technological challenges, there will be a mature personal robot product series in line with the infrastructure of robotics industry for coming next 10 to 20 years. By a scenario methodology a future robotic society is plotted to examine what will be needed necessarily in constructing market and how to layout a convincible business strategy for those who wants to play in robotics industry.

The financial crisis restricts lending and financing of new initiatives in private as well as public organizations. Especially SMEs are unable to gain sufficient funding for their development and this reduces, and in some cases even terminates, innovation and growth in the private sector. Thus, investments in growth and innovation are under pressure and the current crisis even appears to be deeper and longer lasting than expected, but the robotic market and it’s global trends can be affected due to following items:

- Robot performance will be improved. Robots will be applied to the fields where no robots have been used, and the market of the industrial robots will expand.
- As the robot technologies progress, work that can only be carried out by human beings will be reduced and automatic work done by robots and man-robot
- Cooperative work will increase. As a result, the Japanese manufacturing industries will maintain their international competitive forces even in the age with a low birth rate and many elderly people.
- Robot teaching operations will become simpler, and cost performance will improve further. As a result, robots are used more widely in not only large-scale enterprises but also middle- and small-scale enterprises, contributing to

solution of manpower shortage in middle- and small scale enterprises.

- Structuralization of environments where robots may work easily may be easier in factories than in homes and general society environments. In cooperation with development of intelligent robots, such environment structuralization will expand the areas to which industrial robots may be applied.
- As the industrial robot capability is improved, the technical results will have influences upon nonmanufacturing fields and contribute to development of robots for various non-industrial uses.
- In the age with a low birth rate, people liberated from the manufacturing industry may be engaged in work in various fields, manpower will be re-distributed, and the active power of the society will be maintained.

While the last 25 years saw tremendous progress due to the Internet, the next revolution is considered to be robotics. Robotics has the potential to be a real-game changer for job growth and quality of life. Today the big commercial robotics programs are in Europe, Japan and South Korea. Global trends in autonomous robotic market is summarized and categorized from 1980 till forecasting up to 2020 in Fig. 21. The overall conclusions indicate that in almost all the surveyed countries, not only the potential for robot installations in the non-automotive industries is still tremendous, but it is also considerably high in the automotive industry among the emerging markets and in some traditional markets as well. This is mostly due to the necessary modernization and retooling that is needed in these markets. The trends in manufacturing industries can be summarized in one term: "Green Automation". Energy-efficiency, reduction of CO^2 output and quality management are the main factors of future production processes in all industries. The successful robot suppliers will be the ones that can provide the right solutions for the industry in order to face the challenges ahead. After the substantial fall of robot sales in 2009, an increase will resume in the period between 2010 and 2012 about 15% per year on average attaining a level of more than 100,000 units. The strong decrease in 2009 and the slow recovery will result in a more or less stagnating operational stock in the forecasted period.

1980 ~ 1990

- society was ready to accept robots
- industrial robots were popularized in car industry and hand wide applications.

1990 ~ 2000

- Improvement of production efficiency (welding, handling, inspection, painting, assembl, mounting, etc.).
- Attaching much importance to product quality
- Communication (between robots and other equipment)

2000 ~ 2012

- Safety standard was revised. (coorperative work with menhuman beings were enabled.)
- Cell manufacturing enabled production of many kinds of products..
- Accuracy improvement due to progress of robot-workpiece relative position control.

2012 ~ 2020

- Market of highly intelligent robot expanded sharply worldwide.
- Estimated sales of robots in Japanese market increased sharply.
- Expanding of interactive robot with simplified operation.
- Increase of sensor utilization, higher speed mommunication and more accurate sensors will be enbaled.
- Weight reduction (high rigidity) due to progress of material technology and improvement of mean power rate due to further progress of motor and drivers.
- estimated sales of robots in Japanese market moe than 6 trillion yen.
- Improved intelligence due to progress of offline teaching and interface technology for efficient information exchange between robots and human.

Fig. 21. Global Trends in Robotic Market

In most of the traditional robotic markets the stock will stagnate or even decrease, while in the emerging markets it will further increase. Meanwhile future products and systems in robotic market are becoming:

- Smarter, Faster
- Greener
- Smaller
- Nicer
- Cheaper

Robotics enables existing industry and will create a new industry. The trend towards automation will go on. Industrial robots are a key component in the automation of processes, and automation is the key to a more eco-friendly production, to rising productivity, to more quality and safety of the work place and to solve the problem of demographic shifts in our societies.

6.1 Robotic Future Vision

As a matter of fact, the design of advanced robotic systems is moving from the classical concept of precise and stiff structures, often heavy and very complex, to that of light and flexible ones, with the perspectives of in- creased performances, high mechanical simplification, and consistent cost reduction. Robot future application and vision are estimated as follow:

❖ **2011-2015**

- Robot dance tutors
- Nano walkers, nano worms, nano fish
- Mechanical intelligence using MEMS and NEMS (early stage)
- Android robots used for factory jobs (prototype HRP-3 Promet MK II)
- Fleet of garden robots for plant and lawn care and tidying Robots for cleaning, washing fetch and carry, in office (prototypes)
- Robot pest killers (some prototypes)

❖ **2013-2017**

- Housework robots - fetch, carry, clean & tidy, organize etc.
- Robots for guiding blind people (First car drive of blind person 2011)

- Cybernetic use in sports (Ossue Flex-foot, Otto Bock C-Leg)
- Robots for cleaning, washing, fetch and carry, in home (Roomba, Scooba, prototypes)

❖ **2016-2020**

- Self diagnostic self repairing robots (?)
- Actuators resembling human muscles (Polymer Actuators research)

❖ **2020s**

- Insect sized robots banned in gardens due to effects on wildlife (UAV restrictions already discussed)
- Robotic delivery for internal mail (AGVs)
- Robotic exercise companion (TOPIO robot play ping-pong with humans)
- More robots than people in developed countries (very optimistic)
- Android gladiators (EU FET Flagship project Companion Robot for Citizens)
- GM and robotics converge, GM used to make organic robots (artificial meat projects)

❖ **2030s**

- Micro-Mechano fractal construction kit

❖ **2040s**

- i-Robot style robots with polymer muscles and strong AI

a vision of near future of robots are estimated as follows:

❖ Robots will be everywhere,

- In the factories
- In hospitals, public buildings, schools, services firms…
- In cities' streets
- In every home

❖ To assist, educate, help, and entertain people,

- Less chores
- Less risks
- More productivity
- More time
- Smart jobs and smart life

❖ As distributed intelligent systems or multifunctional companions

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