A Study of Personal Service Robot Future Marketing Trend

With The Foresight of Technological Innovation

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Abstract

The new market for the robotics can be concluded into industrial service, personal service and professional service three segments. For personal service robot (PSR) segment, utilizations are including entertainment, education, home security, medical care and house work routine etc. Professional service robot is mostly considering for harmful mission substitution such as working in hazard environment, cramped space exploring etc. it usually involves lots of unique technologies and technological integration at certain technical difficulties and challenges. In this paper, we are targeting on PSR segment. It is aimed to related information collecting from the past to date, through a system categorizing and by using technological forecasting technique; we try to sort out all related critical technologies and to project the technological trend of personal service robot applications. In confronting with potential enormous PSR market growth next ten to twenty years, technological road map and breakthrough, is the key to determine the business viability in competition among all for PSR industry. In other words, technological innovation is the critical base to lead robotics industry to be prosperous. This study try find out specific technological road map and identifying the critical path that may impact the market wellness. Meanwhile, understanding the "technological push" or "marketing pull" through marketing strategic analysis and categorizing.

Keywords: *Robotics; personal service robot; technological innovation; technological forecasting, marketing strategy*

1. Introduction

For the decades, Robot is kind of our life matter that always sticking around daily. A clear definition about the “Robot” and “Robotics” is given accordingly in the paper. although the idea of “Robot” existed from quite long time ago, but how would the concept formed and changed alone the historic axis through different social background will be part of our theme in this paper, we are also giving a brief of story telling about the “Robot root” and to sort out different scenarios with the perspectives of sociological and scientific view angle about robotics.

As various application concept of what Robot can do with dedicated design for it, we define contemporary application field into three major categories of Robot as robotics focus, Such as Industrial Robot, Professional Robot and Personal Robot. From the milestone of robotics, we are putting all information that we collected to see how technology brewed and how they became juice fruits in certain segment.

The contemporary technologies review in robotics is to bring up the entanglement between the technological push and market pull for today and tomorrow. However, mankind has long expectation about the robot and getting their perception from mysterious legend turning to scientific reality, followed industrial robots were successful adapted in the production line globally, Personal robot development is becoming an intensive knowledge domain in the academia and research institutes of global enterprise such as Sony[1], NEC[2], Philip[3] .. etc.

The key of technological breakthrough that moves scientific fiction to become scientific technologies in robotics was discussed and proved that mainly is ascribed to computer technology and its derived applications in terms of Information Technology. What are the major challenges in front of on going development of will be summarized as a technological road map for personal robot.

As we can see 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.

2. Background of Robot [4]

The idea of artificial people dates at least as far back as the ancient Greek mythology, legend of Cadmus [5], He sowed dragon teeth that turned into soldiers, and the myth of Pygmalion, who fell in love with statue of Galatea that came to life. In classical mythology, Hephaestus [6], the deformed god of metalwork, created mechanical servants including intelligent, golden handmaidens and three-legged tables that could move about under their own power. Also, Jewish legend tells of the Golem, a clay statue animated by Kabbalistic [7] magic. Similarly, In Norse mythology tells of a clay giant named Mistcalf constructed to aid the troll Hrungnir in a duel with Thor, the God of Thunder.

In the 1950s, Da Vinci's notebooks were discovered, and in these notebooks specified detailed drawings for a mechanical knight that was apparently able to sit up, wave its arms, and move its head and jaw. This could be the first recorded of designs of a humanoid robot and made by Leonardo da Vinci around 1495. The design was likely based on his anatomical research recorded in the *Vitruvian Man*[8]. It is not known whether or not he attempted to build the robot.

The first use of “robot” term is a Czechoslovakian playwright named Karel Capek [9] who actually coined the term "robot" in a play called *R.U.R.* (Rossum's Universal Robots) from the Czech word "robota," meaning obligatory work or servitude. This is an idea that reflected the desire from mankind to have a long last operated, with full of energy and dedicated work force for mankind, service the mankind. Around the World War I, rapid industrial growth needed lots of labor force and that is why such a play of “super labor force” was introduced and its concept began to spread wildly over the France, Japan and other European countries.

From the time being, the concept of “robot” has escaped from mysterious legend and getting into scientific fantasy. It is a theme that never seems to lose the public's interest, although it was a long journey for science to develop its related knowledge and technologies to date, all of us were grown up and inspired with thousands of scientific fictions, comic and movies themes of robot. However, those crude and campy robotic fantasy images inspired children’s minds that grew to drive the evolvements to the actual robotic products as they exist today.

Here are the latest definitions, Robot: "A machine devised to function in place of a living agent; one which acts automatically or with minimum of external impulse" or "An automatic apparatus or device that performs functions ordinarily ascribed

to human beings or operates with what appears to be almost human intelligence."

2.1 Development of robot application in real world [10]

In 1946, George Devol [11] patented a general purpose playback device for controlling machines, and 10 years later George Devol and Joseph Engelberger formed the world's first robot company. In 1961, the first industrial robot was on a production line a General Motors automobile factory in New Jersey. It was called UNIMATE. The first commercially available minicomputer-controlled industrial robot is developed by Richard Hohn for Cincinnati Milacron Corporation in 1973; the robot is called the T3, The Tomorrow tool.

1980's, the robot industry starts its rapid growth, with a new robot or company entering the market every month. Robotics was heading into wider and deeper technological challenge – Humanoid robot. In 1986, Honda begins a robot research program, the main axis of development is based on that the robot "should coexist and cooperate with human beings, by doing what a person cannot do and by cultivating a new dimension in mobility to ultimately benefit society." By MIT Mobile Robots Group [12], in 1989, a walking robot named Genghis was presented and It becomes known for the way it walks, popularly referred to as the "Genghis gait".

1998, The "animatronic pet", to uses a variety of sensors this can react to its environment and communicate using over 800 phrases in English and their own language "Furbish", was introduced by a toy company -Tiger Electronics[13]. This is the first robotic pet in successful commercial segment. Next to it, SONY releases the AIBO robotic pet in 1999, and Honda debuts new humanoid robot ASIMO in 2000.

From the earlier day's articulated type of industrial robot arm to nowadays mobile, autonomous, and self-learning robots, the development process it presents mankind with a determination on the way to create reliable company who can serve the human, even more to protect human without a word. As achievement has been made today, we can categorize all the development based on their design purpose, function and final application into three major types of robot, they are Industrial Robot, Professional Robot and Personal Service Robot.

2.2. Industrial Robots[14]

The industrial robotics segment consists of immobile, single task robots that have little interaction with humans or the world around them. They are termed industrial robots because they are exclusively employed in manufacturing and factory floor automation. They are actually the articulated robotic arms, responsible for spot welding our cars, painting our refrigerators and checking for

irregularities in assembled products. As of today, total accumulated yearly sales measured since industrial robots started to be introduced in industry at the end of the 1960s, amounted at the end of 2004 to some 1,500,000 units. A precise measure made by UNECE and IFR estimate the total worldwide stock of operational industrial robots at the end of 2004 between a minimum of 848,000 units and a possible maximum of 1,120,000 units.

2.3. Professional Service Robotics

Professional service robots are used to serve where work is repetitive requires continuously high levels of concentration and in dangerous environments that human cannot afford. The areas where professional service robots are working, or in development, includes, but is not limited to, industrial cleaning, equipment maintenance, and data acquisition. Medical/healthcare robots such as rehabilitation robots, prosthetic and orthotic devices are the type. The robotic rovers Spirit and Opportunity currently hurtling towards Mars are exploration and discovery service robots. Inspection, security, construction, demolition, delivery are all services now provided by professional service robots. For the military, robots mainly function for search and rescue, fire fighting, de-mining, surveillance and other types of public safety robots, all of above are counted as professional service robotic segment.

2.4. Personal Service Robotics

Robotics Trends [15] defines Personal Robots as robots or robotic technology purchased by individual buyers (consumers) which educate, entertain or assist in the home. The personal robotics market serves the consumer market in many diverse segments and is typified by products such as home automation/domestic service robots (robotic vacuum cleaners and home security robots, for example), hobbyist/education robots and entertainment robots (Lego's Mindstorms and Sony's Aibo robot dog serve as examples, respectively). Intelligent mobile toys such as Hasbro's Fur Real Friends [16], along with those robots that assist the disabled and elderly in the home, also fall into the personal service robotics category.

As today's technology and market trend shows, personal service robot will be realized and fully boomed in the next 10 to 20 years, all domestic functions to personal assistance will be covered and provided by "Robotic" application. It will be our main interest to survey how the living society would be in counting with future robotic services after the year of 2020.

3. Technology Review

A typical concern of robot service is safety. Many of scientific fictions built an impression to peoples' deep in heart that "Robot" becomes enemy of mankind through intelligent mutation, beside Asimov's Three Laws of Robotics [17]:

1) A robot may not injure a human being, or through inaction, allow a human being to come to harm.
2) A robot must obey the orders given it by human beings except where such orders would conflict with the First Law and
3) A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

From an overall challenged view, robotic development is always on the way to mimic the human with following two segments in scientific field: [18]

1) Validation of bioengineering models, the idea pursued by some scientists along this line is to develop a physical model, both at the level of sensors and actuators and at the level of sensory data processing, sensory motor coordination, and behavioral schemes, implementing and validating bioengineering models.

2) Replicating humans. The idea is to develop robots that have a biomorphic appearance and are able to behave like humans.

However, the main technological tasking is to make sure robot was built to understand human instruction and desire and then to perform adequately in correspondence through its well designed functionalities – Robot-Human Interfacing technology.

The interfacing technology can be divided into three elemental domains of sensory technology, motion technology and intelligent technology and they are the critical factors for robotics to be successful.

The interfacing technology has different orientations but all are the same mainly to perform the communication between human and robot. (See Fig.-1)

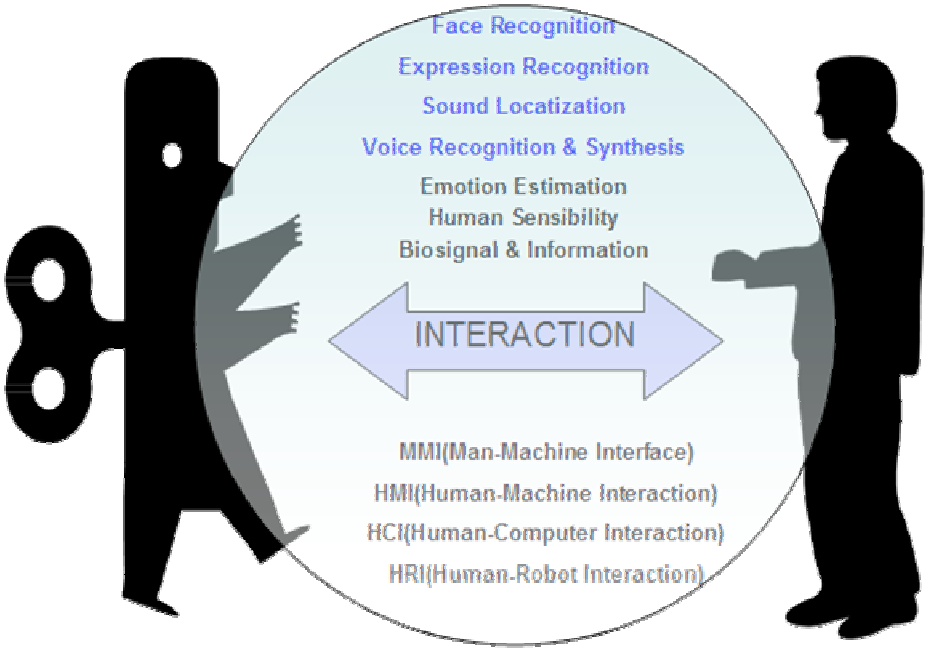

Fig.-1 Interfacing between Human-Robot

In addition to basic robotic functions (sensing, motion control, navigation, etc.), technologies under developing for the personal service robots are focusing on followings [19],[20]:

- Spatial-temporal cognition: object learning and recognition, scene and situation interpretation and understanding.
  - Enables a robot to recognize human faces, obstacles, etc. through images picked up by cameras. [21]
  - Measures/examines the position and the distance of objects based on the information by ultrasonic and infrared sensors.[22][23]
- Decision making: choice (reflexive) reasoning, anticipation, planning.
  - Generates movements after integrating and interpreting results of image/voice processing, memory, actual situation, and other factors.[24]
  - Clever and intelligent behavior judging by memory and actual situation, based on the circumstances of autonomous motion and appropriate action.
- Learning: new/improved skill, new knowledge from acquired information (deduction, induction, abduction). Open ended.

- Intelligent operation system with tasking language programming design.[25]
- Learning by imitation and demonstration.

• Interaction and communication: task ability, intention expression, explanation.

- Recognizes spoken words and generates the robot voice.
- Speech source localization: Determines the speech direction of arrival.
- Speech Synthesis and smart conversation with humans and adequate correspondence

It is a complex domain for service robotic technologies in development; the related technological domains which are involved can be put as a supply chain shown in Fig.-2 and a forecast of technological roadmap of robotics is also showing in Fig.-3.

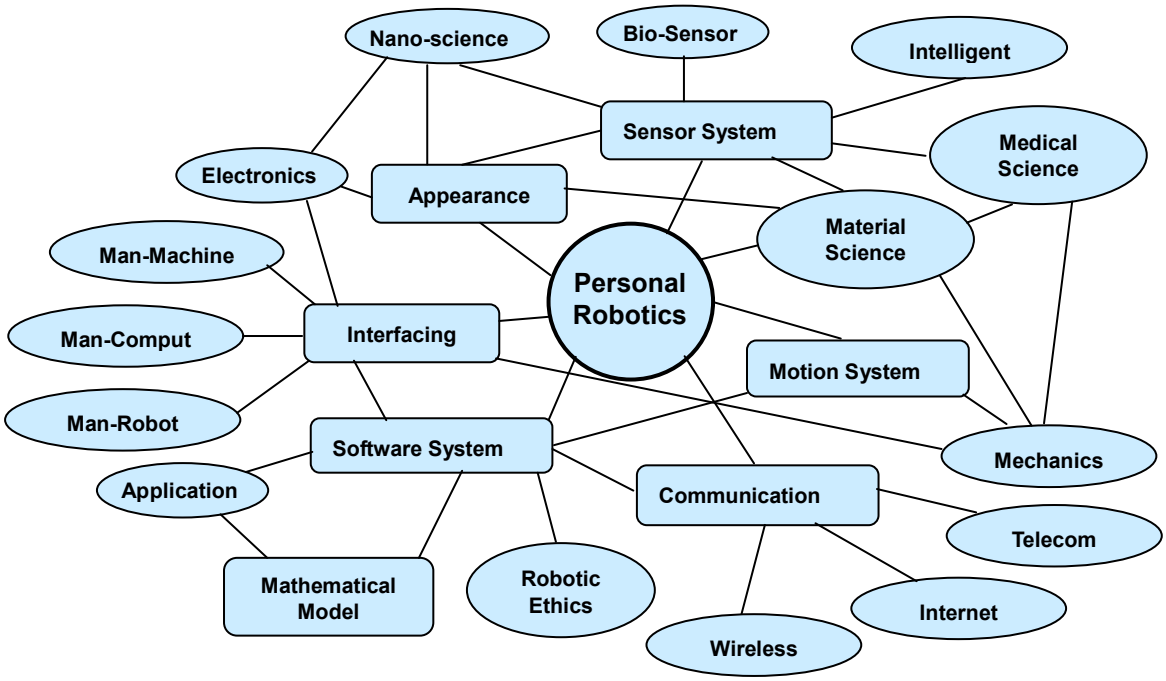

Fig.-2 Robotic Technologies and Supply Chain

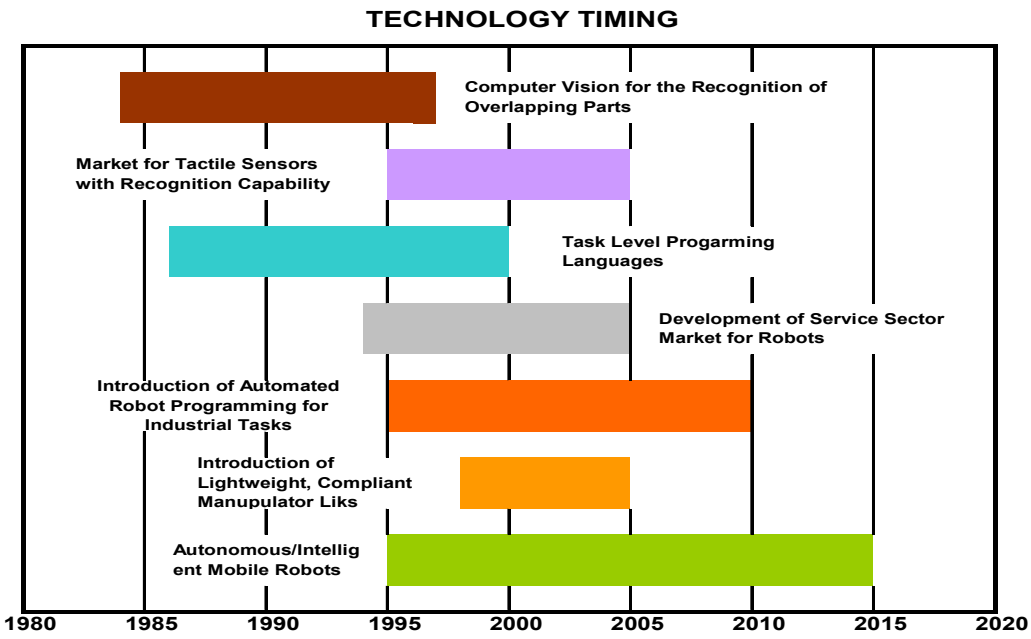

Fig.-3 Robotics Technological Roadmap

4. Market Review in Service Robots

This market review is made basically for professional service robots and personal service robot, the statistic are provided by the publishing of " World Robotics 2005" done by The International Federation of Robotics (IFR) in cooperation with the United Nations Economic Commission for Europe (UNECE)[26] .

4.1 Professional service robots

There are 25,000 units installed up to the end of 2004, with 5,320 units, 21% of the total number of service robots of underwater systems accounted for professional use, 14% of cleaning robots and laboratory robots, 13% of construction and demolition robots, 11% of Medical robots and mobile robot platforms for general use, 9% of Field robots, e.g. milking robots and forestry robots, and 5% of defense, rescue and security applications. (Fig.-4)

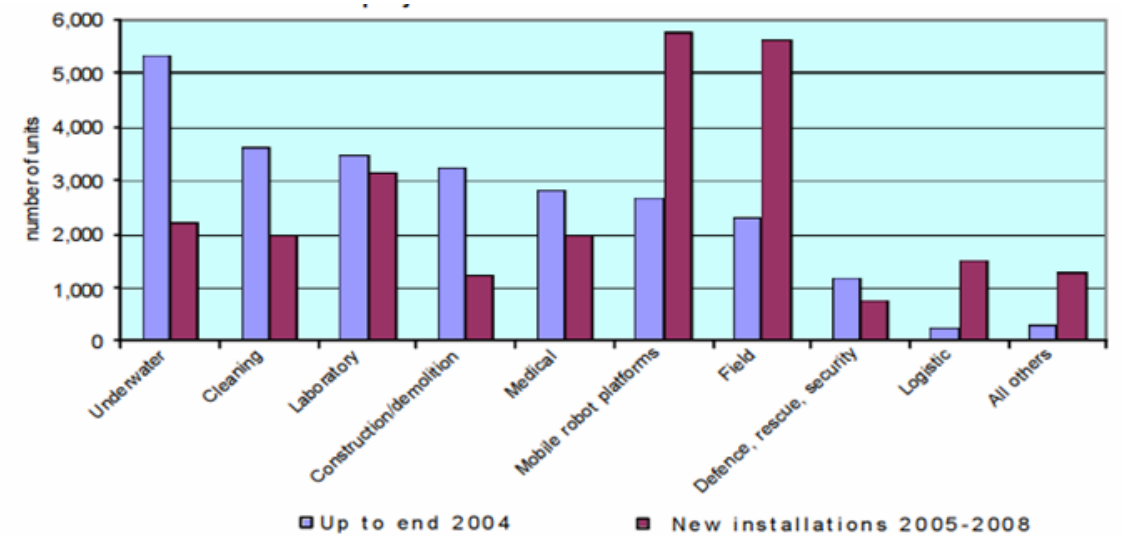

Fig.-4 Service robot (unit) for professional use

The value of the stock of professional service robots is estimated at $3.6 billion. The unit prices for professional service robots differ significantly – from less than $10,000 to more than $300,000, depending on type of application. The most expensive robots are underwater systems (from $300,000 to more than $1,000,000), medical robots with a wide range from $100,000 to some $1,000,000, and milking robots ($200,000).

Turning to the projections for the period 2005-2008, the stock of service robots for professional use is forecast to increase by some 50,000 units. Application areas with strong growth are humanoid robots, underwater systems, defense, rescue and security applications, laboratory robots, professional cleaning robots, medical robots and mobile robot platforms for multiple uses.

4.2 Personal service robots

For personal and private use, there are about 1.2 million units for domestic use and more than 900,000 units for entertainment and leisure sold up to end 2004

Main areas of domestic (household) robots include vacuum cleaning and lawn-mowing robots, and entertainment robots, including toy and hobby robots (see Figure-5). Sales of lawn-mowing robots have started to take off very strongly, with sales in excess of 46,000 units, and should continue to boom. The market potential is very large. Vacuum cleaning robots were introduced on the market at the end of 2001. The market expanded rapidly in 2002-2004 and at least one million units have been sold. Of the 1.2 million robots for domestic household robots that were in use at end 2004, about 550,000 were installed in 2004.

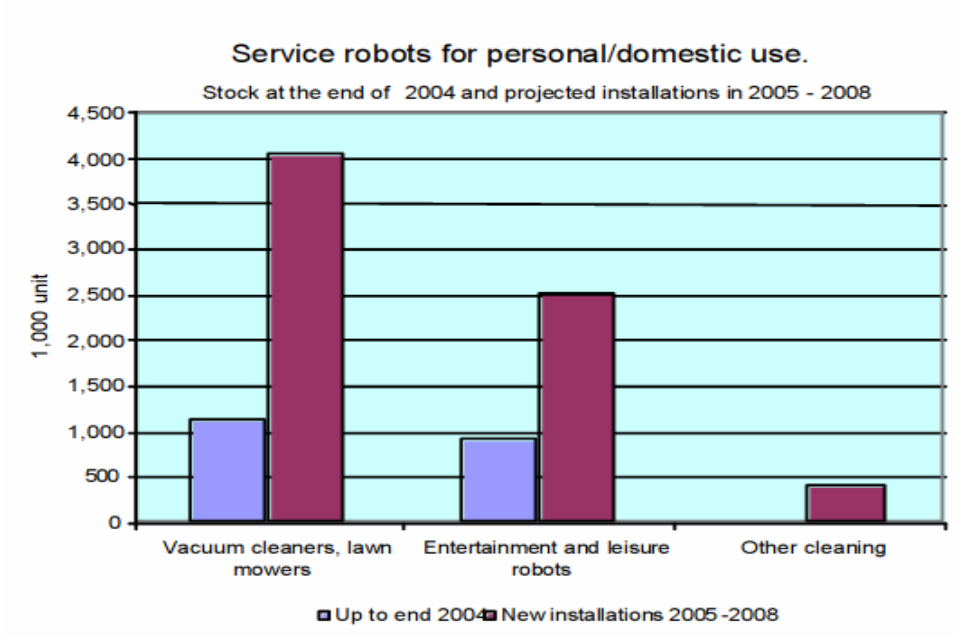

Fig.-5 Service robots (unit) for personal/domestic use

Projections for the period 2005-2008: about 7 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) in the period 2005-2008 could reach some 4.5 million units with an estimated value of $3 billion. (Figure-6) The market for entertainment and leisure robots, which includes toy robots, is forecast at about 2.5 million units, most of which, of course, are very low cost. The sales value is estimated at over $4.4 billion.

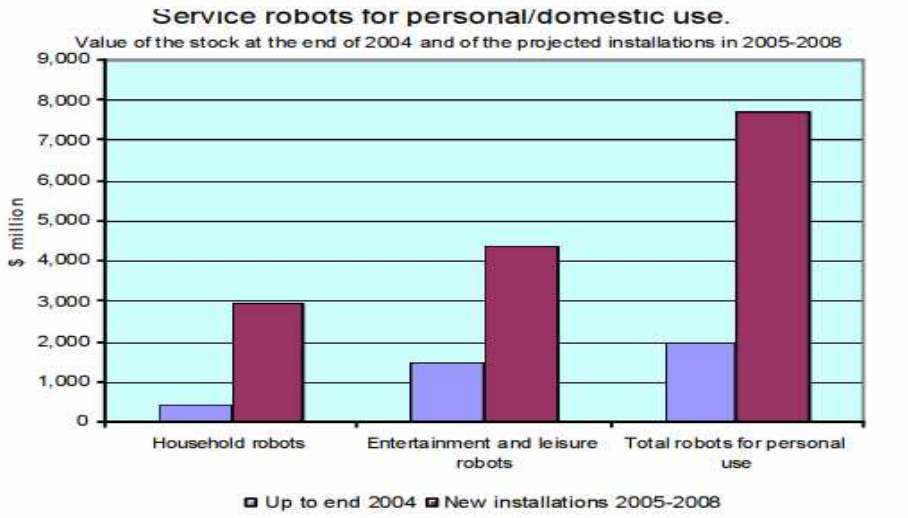

Fig.-6 Service robots (value) for personal/domestic use

From a Japan Robotics Association (JRA) study, data for the service and personal robotics market can be derived by combining the public sector, medical, welfare and home markets. According to the JRA (Figure-7), the service and personal robotics marketplaces together will be 17.1 billion for 2010 and 51.7 billion for 2025.

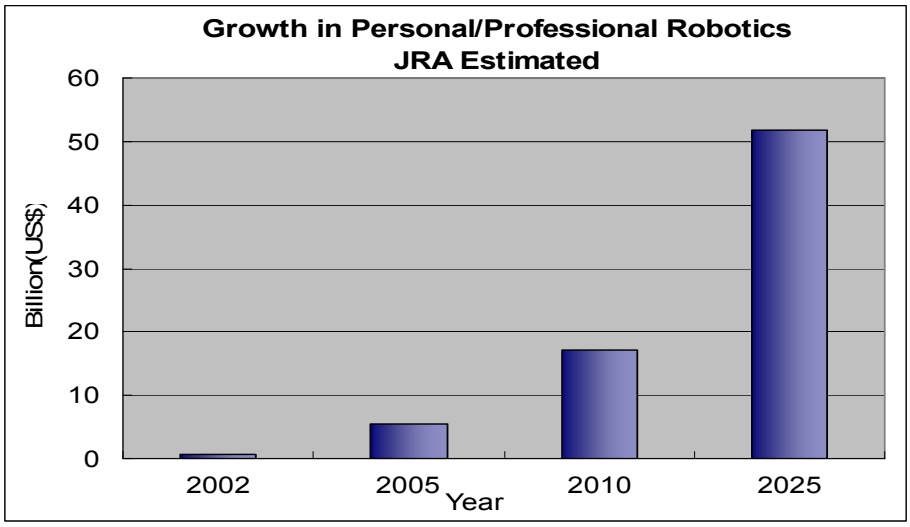

Fig.-7 Projected growth (value) of personal/professional Service robots

5 Forecasting for future Personal Service Robot from foresight outcome

In this section, we are going to present the study of future development in Personal Service Robot based on a foresight process result with respect to technology, application and market issues with the scenario generated in a time frame of 2015 to 2030. The foresight outcome of robotic technology is based on two sources, European and Korean (See Figure-8 and 9), from the source we can see both indicated the technological roadmap for personal robots will be matured and entering to commercial massive market by the year of 2010 to 2015.

According to these this scenario, we can, of course, foresee the products that supported by technology is not a problem for targeted applications (Fig.-9), but by the time of when products are available for the market and applications, what would be the demanding for these product combine with other technologies to get a better service and fully utilizing the overall benefits that new technological environment can bring into us?

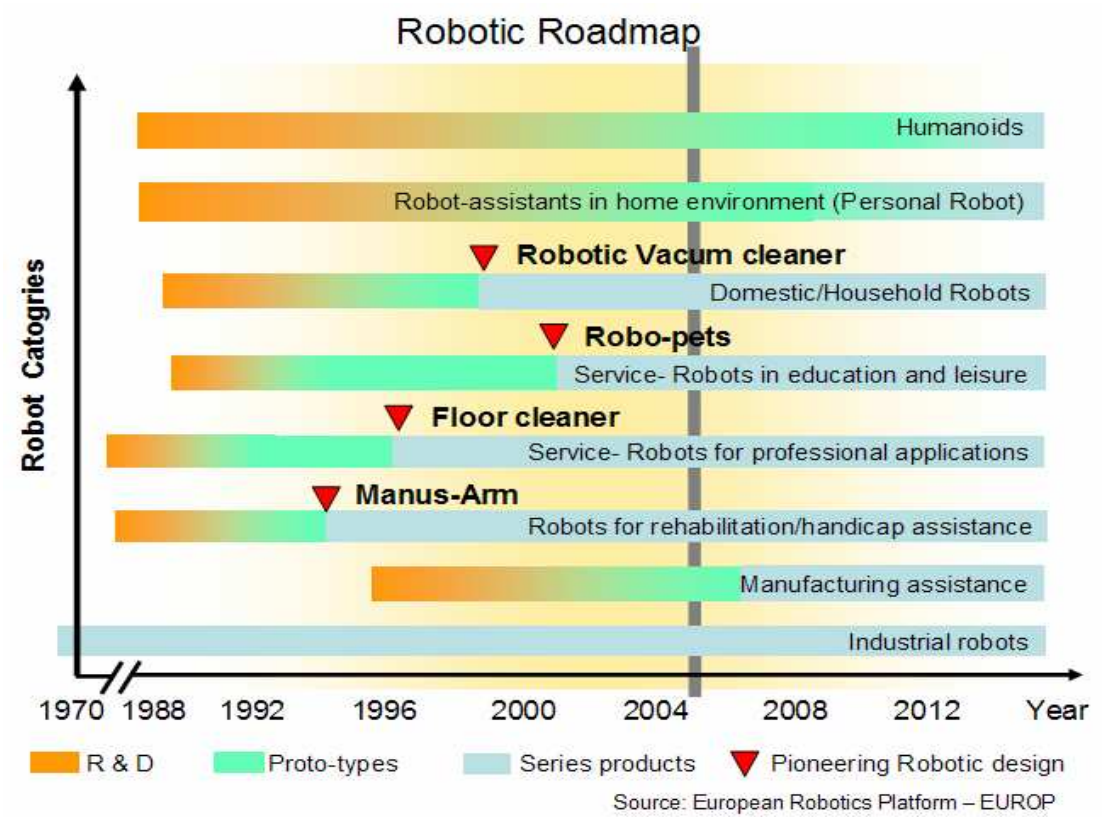

Fig.-8 Robotic Roadmap

Here we would survey all related technologies, especially in information technology, to see what would be an ultimate format of personal service robot that will be adapted into future development in both of technology and market.

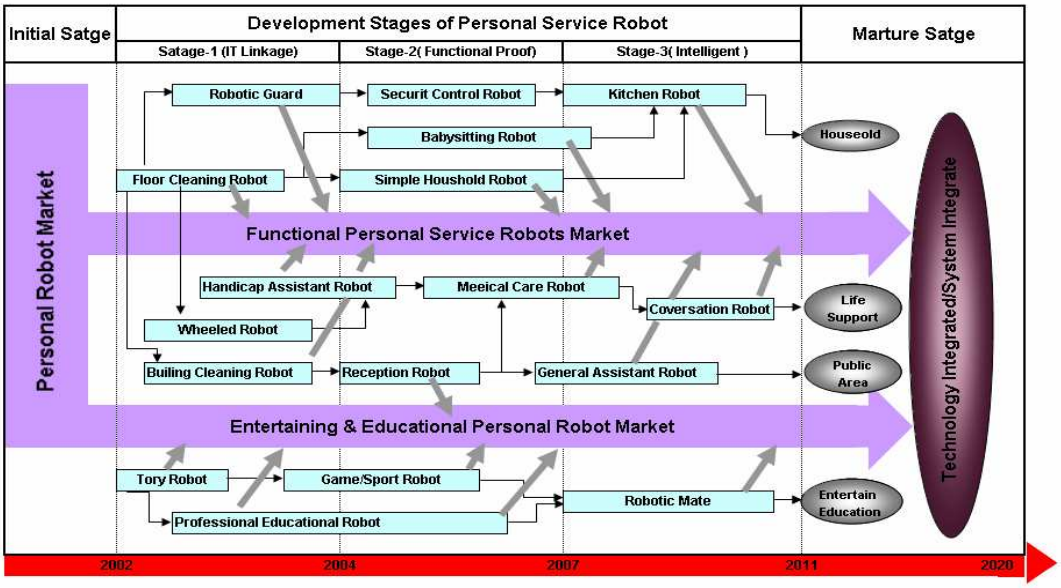

Fig.-9 The Roadmap of Personal Service Robot

Source: Derived from Korea Association of Robotics

As the result we made can be a decision support for the future research in technology and prioritizing the strategies for future business action for the development of Personal Service Robots.

As project initiated, a 12 members committee, consisting of 3 members of academic researcher, 4 members of industrial experts and 5 members of project group, was formed to be responsible for project exercising to perform researching, workshop and scenario generating.

5.1 Overall Project Flow

In order to run an efficient study of future technology and market for personal service robot, a foresight concept [27][28] is applied and the project is proceeded on the flow designed as Fig.-10 shown.

Fig.-10 Process Working Flow

2.5.Recognition of the Topic

A forecast process of future Personal Service Robot with respect to technology, application and market issues in a time frame of 2015 to 2030 was defined to be our project axis; the scope is centered on Personal Service Robot and extended to related supporting technologies as involved.

5.3. Technology Mapping & Scanning:

To prepare an overview of robotic technology and to determine the technological domain that ensures all the related aspects of technologies and issues were recognized. By laying out the supply chain of robotics industry as the basic scope for technology mapping, we figure out the related supply chain (Figure-2).

With open literature study and working group discussion and scanning, there are total 38 statements were made to future applications/functions of personal service robot. (See appendix, Table 1). After reviewing on these statements, 11 categories of sub-topic were identified (See Table-1). These 11 sub-topics are the base for holding the further discussion and scenario generating.

Table-1 Sub-topics of Future Personal Service Robot Technologies

Sub-topic	Code	Counts
System	SY	10
Security	SE	3
Personal Assistance	PA	3
Information	IM	2
Interfacing	IF	3
Identification	ID	2
Household	HH	4
Health Care	HC	3
Entertainment	ET	3
Education	ED	2
Communication	CM	3

5.4. Final Analysis/Scenario Synthesis

With these 38 statements, 11 sub-topics, committee performed the final review and analysis of technologies and confirmed the applications, and scenario was also made for each accordingly.

5.4.1. System

"System" indicates the technologies that required enhancing the functions of robot that can be used in future to conform to the expecting application.

The scenario is made to this way, a robot, in the future, must be able to move around the house with the ability of learning navigation, also, and must be capable to provide the standard interfacing for home appliance control. For the robot itself, there is the way to protect its system in case of power low or external impact. With a computing capability, robot is offering home computer server function to

support each tasking that required from family members. The connection between individual to robot is a device so called - Personal Mobile Digital Platform (PMDA) which send/retrieve data via robot. Software level must be virus resistant to prevent the damage from information flow.

5.4.2. Security

"Security" is defined whatever regarding of human safety issue that should be provided by robot. Either visible or invisible life threatening from the environment should be monitoring and alerted by robot, individual's location can be tracked through GPS and PMDP by robot at home.

5.4.3. Personal Assistance

"Personal Assistance" refers to personal data process ability that can be help by robot.

As digital data come to our life daily, schedule, memo, to-do list and personal information management, etc. with the connection between PMDP and robot, all can be handled by robot instead of Personal Digital Assistant today. Furthermore, all the expenditures with the transaction records can be submitted to robot for personal accounting and/or family accounting purpose.

5.4.4. Information

"Information" is function for family and personal needs.

It is mainly a message distributing center provided by robot, it covers personal mail box, message box and bulletin board. It can also be a personal information storage manager connected to internet storage for personal or family use.

5.4.5. Interfacing

"Interfacing" is the technologies that are necessary for a robot to interact between itself and human.

Robot should be able to recognize family member via image or voice or both, to react adequately in correspondence. A localized text to speech function will be included, i.e., robot can talk and make conversation with human.

5.4.6. Identification

"Identification" is the technology of accessibility of family members to log in to use or to command robot functions.

Robot is always monitoring the individual while they are home through RF identification system, to connect PMDP with robot system, DNA identification

log-in is required to ensure the system security.

5.4.7. Household

"Household" means the functional design for robot to handle the housekeeping tasks.

Household function is necessary for now and ever, house cleaning, kitchen activities are the basic functions that robot will provided by it or with the functions doing by different devices/units that were managed by robot.

5.4.8. Health Care

"Health Care" is defined the technologies that can access or monitor the individual health of family members. For general, individual's routine healthy check such as body temperature, heart bit rate and blood pressure are checked and recorded. For special monitoring for elder people, chronic disease, such as diabetes, etc. the data collected can be recorded and transmitted to appointed medical center as needed.

5.4.9. Entertainment

"Entertainment" function covers all video/audio – so called multimedia programs that requested by the individual or family, Music, movies, game or TV programs are all integrated via IT network to be delivered to home, the connection with the robot to home appliance or PDMP, family members can run entertainment on demand accordingly.

5.4.10. Education

"Education" function is similar to entertainment function, for those remote e-learning or education programs can be diverted into home robot system. By different education level required, robot can be interactive to the learner differently for better learning efficiency. In addition to academic learning, robot can be a home tutorial assistant for student to improve the understanding of the subjects. For the child before school, robot can be a companion as babysitting while adult is temporally away.

5.4.11. Communication

"Communication" represents the functions and technologies for personal to person communication channel. World Wild Website, Tele-communication, SMS and VoIP phone and etc. were eventually to be integrated into a system – internet. While infrastructure (bandwidth, wireless connection everywhere etc.), is getting more

mature and ready to carry all data transmitting via internet, hand phone will be VoIP function designed in PMDP, Notebook function can be replaced by Terminal function provided by home robot to PMDP.

It is quite obviously that the personal service robot in the future, after 2015, is not just a robot that we are thinking today, by the time of personal service robot is mature in market and accepted by users, other technologies are also valid to run into home service. In the way of technology progress, future personal service robot may be a mighty house keeper at home for each family. Combine with IT technology and robotic technology, a powerful robotic computer at home for each family in the future is plotted.

6. Conclusion

According to 38 statements (See appendix) unveiled there will be an interesting integration of overall function of future personal service robot which is not only a single tasking machine, further more, it combines today's robotic concept and information technology to form a mighty house keeper. Such as home media center, home appliance control, home security, health care/elder assistance, household tasks and individual's activities support etc. All of these can be managed by future personal service robot. As future information network will support 50M bandwidth to the home, WiMax accessibility for everywhere, our daily life will be covered by a future robot stayed at home to provide us all information that we ever need through local network and internet. For example, with the personal mobile digital platform device, family member's position information through GPS can be transmitted back to mighty house keeper via internet and to be tracked. Family member can keep all his/her information in internet storage through robot and any learning activity can be guided by robot when it is requested. Foreseeing that personal service robot of future will be a mobile, intelligent and humanoid computer, it is also a member of family and knowing how to comfort, to teach, to entertain everyone – human member, of the family.

Here we also bring new system concept for current technological innovation:

- Personal Mobile Digital Platform (PMDP), it acts as client of home robot server. The function provided from robot server is a combination of nowadays' devices: PDA, hand phone, Notebook and GPS plus extra sensorial designs such as DNA authentication, Health monitoring sensorial system and other particular applications.
- Home Robotic Computer server, similar to corporative server for business

operation; it could be a simple model to reduce the amount of personal computers by using the system of Home Robotic Computer Server to personal clients. All the software just built into server and to be utilized through networking setup.

- Personal position tracking system, by utilization similar to car security system in America, When PMDP is a viable device to stay with individual of each family members, a security system to mankind can be built as car security today.

There must be wider coverage of technologies regarding of future Personal Service Robotic development, the more time and efforts were spent and clearer picture can be accurately formed. As of today, we have presented some of technologies that are available for future applications; the vision needed is the focus that looks into future application and starts to work on that to form a technological push for future market.

In the other way, there are some demands that will come from the future society as long as technological development is reached, and the living environmental base is totally upgraded. To realize that and to prepare necessary approaches for the new era is the way to lead the business running in a secured way for now and next.

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Appendix

Key technology and application statement of personal service robot

No.	Statement	Code
14	Navigation and self learning	SY
16	Descend/ascend stair motion	SY
19	PMDP is attached to PSR	SY
20	Home appliances control	SY
28	Self Power management	SY
29	Emergency handling function	SY
31	Multi-Tasking design	SY
32	Standard interfacing for individual robot unit	SY
33	Anti-Virus Operation system	SY
34	Robotics ethics enhanced	SY
1	Toxic gases monitoring	SE
9	GPS Tracking of each member of family	SE
15	Security for home staying	SE
6	Personal assistant	PA
22	Personal accounting	PA
23	Tax/payment handling	PA
5	Personal information center	IM
18	Auto message distribution and bulletins board	IM
2	Expression recognition for family members	IF
10	Text to speech Voice synthesizing	IF
21	Data acquisition and analyzing	IF
3	Identification through RF ID	ID
4	Authentication via DNA for system link	ID
12	House cleaning	HH
13	Atmosphere control (refreshment)	HH
25	Vacuum Cleaning	HH
26	Reception	HH
11	Health care/medical check routine	HC
27	Elder person assistant	HC
30	General health monitoring for family member	HC
8	Entertainment on demand	ET
17	Music box	ET
35	Game on Demand	ET
7	Education on demand	ED
24	Babysitting/Tutorial	ED
36	Internet connection	CM
37	Telephone network connection	CM
38	Local wireless connection	CM