A Technical Analysis of Autonomous Floor Cleaning Robots

Based on US Granted Patents

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Abstract

Autonomous floor cleaning robots are getting more popular for busy and aging populations. A technical analysis of residential floor cleaning robots based on US granted patents is presented in this paper.

Macroscopic analysis of patents, patent bibliometrics or patent maps, is useful tools to make an overview for designated technical topics, but may misconstrue patent value because lack of case review. Microscopic point of view can construct technical value and development of each patent and patent series but need labors and time. Applying both methods alternately, using a bubble map to be a bridge in this paper can get precise results.

Samsung is the top one patentee in cleaning robot after macroscopic of view, on the contrary, iRobot get the first position after microscopic analysis.

Keyword: patent analysis, cleaning robot, autonomous robot,

1. Introduction

Service robots have been getting popular in recent years, these robots operate semi- or fully autonomously to perform services useful to the well-being of humans and equipment. Service robots of different varieties including medical robots, underwater robots, surveillance robots, demolition robots and other types of robots

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those carry out a multitude of jobs. They can clean floors, mow lawns and guard homes and will also assist old and handicapped people, do some surgeries, inspect pipes and sites that are hazardous to people, fight fires and defuse bombs.

This paper will focus on a service robot of everyday tools for mankind, a cleaning robot in home. Residential robots are quite different from industrial robots because of nonprofessional users. It needs high reliability and safety. Autonomous cleaning robots are getting more popular for aging populations, it is necessary to design ‘really autonomous’ robots, easy to stagnate or stasis are not allowable, especially for old users.

‘A robot in every home?’ reported by Science News in 2004, ‘In the home, by the end of 2003, about 610,000 autonomous vacuum cleaners and lawn-mowers were in operation, the report says. Between 2004 and 2007, more than 4 million new units could be added, it adds.’ New market induced companies devoted to new and functional robots design to get higher market share.

In technical development of varieties and advanced robots, one can find hundreds of papers. Many advanced robots have powerful functions but still a big gap to commercialization. This paper analyzed commercial robots by US granted patents, companies always file patent in advance for their commercial products, granted patents are also a powerful weapon to stop competitors enter their claim technology under its exclusive rights.

Patent analysis for special technical topics can evaluate patent and find the occupied technology, it is helpful and necessary before R&D. Macroscopic of analysis including patent bibliometrics, patent citation analysis, to determine strength and value of a patent based on patent numbers. Patent maps are useful tools to visualize the distribution of patents, monitor the trend of technological changes, infer the strategy of patent portfolios, and compare competitors by statistical charts or diagrams.

Macroscopic point of view may misconstrue patent value because lack of case review. The value of intangible assets should not be estimated only on its numbers. On the contrary, microscopic point of view can construct technical value for each patent but need labors and time. Both points of view applied in this paper, to make a technical strength and development analysis of modern residential cleaning robots by US granted patents. An overview of patent numbers and main patentees in cleaning robots first, then the attained US granted patents were classified and formed a bubble map, two major patentees, iRobot and Samsung, were competitors and analysis under macro and micro point of view.
An overview of fundamental cleaning robots and main Patentees

A fundamental structure of a modern autonomous floor-cleaning robot is complicated, could be illustrated by US6883201 (Fig.1), which is also a successful product of commercialization today by iRobot Corporation, comprises a housing infrastructure, a motive system with wheels, a bumper, a self-adjusting cleaning head subsystem with brushes and vacuum assembly, a removable dust cartridge, a sensor system to detect obstacles, and a control system for autonomous actions.

Fig.1 a fundamental structure of autonomous floor-cleaning robot in US6883201, a perspective view and side, partially sectioned plan view.

Organized suitable search queries and obtained interested patents, an overview of US granted patents in cleaning robots since 2000 is shown in Fig.2. It shows a tendency of increasing, and matches the market prediction in 2004 by Science News. It has not been published in whole year of 2013 on search date, more than 150 granted patents is a reasonable prediction in 2013.

Fig.2 US granted patents from 2000 to 2013(latest search 2013.8.6)
Table 1 is the top 5 patentees who own US granted patents more than 20. Samsung, iRobot, and LG occupy the first three. Samsung Gwangju operates as a subsidiary of Samsung, so Samsung totally got 77 patents will be the first position. Samsung and LG, both are companies of South Korea, have many types of products, Samsung’s major one named Novibot, LG’s Roboking. IRobot, a US Company, has a famous product named Roomba. Table 1 shows scattered patentees, others occupy 79.1%, and each one owns granted patents lower than 20.

Table 1 Main Patentees of cleaning robots

<table>
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<tr>
<th>rank</th>
<th>Patentee</th>
<th>Applications (granted)</th>
<th>percentage</th>
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<tbody>
<tr>
<td>1</td>
<td>Samsung Electronics Co.</td>
<td>89(54)</td>
<td>6.6% (5.4%)</td>
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<td></td>
<td>Samsung Gwangju Electronics Co.</td>
<td>26(23)</td>
<td>1.9% (2.3%)</td>
</tr>
<tr>
<td>2</td>
<td>iRobot Corporation</td>
<td>81(73)</td>
<td>6.0% (7.3%)</td>
</tr>
<tr>
<td>3</td>
<td>LG Electronics Inc.</td>
<td>43(32)</td>
<td>3.1% (3.2%)</td>
</tr>
<tr>
<td>4</td>
<td>Evolution Robotics, Inc.</td>
<td>28(22)</td>
<td>2.0% (2.2%)</td>
</tr>
<tr>
<td>5</td>
<td>Sony Corporation.</td>
<td>27(26)</td>
<td>2.0% (2.8%)</td>
</tr>
<tr>
<td></td>
<td>others</td>
<td>1056(764)</td>
<td>78.2% (76.8%)</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>1350(994)</td>
<td>100%</td>
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Latest search 2013.8.5

Fig.3 is a bubble map for top three patentees in each subsystem of an autonomous cleaning robot, the bubble size is proportional to granted patent numbers in recent 10 years, and counted by human review.
IRobot acquired Evolution Robotics in 2012, makers of the Mint-floor-cleaning robot with an R&D shop focused on navigational tools. The Mint cleaner joined iRobot’s Roomba line. We added ER’s granted patents into iRobot, bubbles in a light color and numbers on left, as shown in Fig.3.
Different Companies devoted to different subsystem and different classification. Fig.3 based on iRobot’s and Samsung’s patents, top patentees may dominate standardization in the future.

We selected top two patentees to be competitors and analytic further. Table 2 is patent family of top two patentees in US, European Patent Office, Japan, China, Korea, and Patent Corporation Treaty, including application and granted patent. Samsung leads in Asia, iRobot leads in PCT, which is an application system managed by WIPO.

Table 2 Patent family of main patentees

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<tbody>
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<td>Samsung</td>
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<td>95</td>
<td>119</td>
<td>130</td>
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<tr>
<td>iRobot</td>
<td>124</td>
<td>104</td>
<td>83</td>
<td>14</td>
<td>46</td>
<td>98</td>
</tr>
<tr>
<td>Evolution Robotics</td>
<td>26</td>
<td>5</td>
<td>1</td>
<td>4</td>
<td>3</td>
<td>26</td>
</tr>
</tbody>
</table>

After macroscopic point of view, microscopic analyses in each subsystem of top two patentees can construct their technical competitions. We constructed technical development of each subsystem, and introduced some patents (not all) in the following.

3. Location recognition and navigation

When a cleaning robot moving on the floor in a room, a blanket movement without any area lost is a fundamental requirement. Two major topic for R&D are location recognition and navigation control.

3.1 Samsung utilized camera and remote control

Samsung developed a robot capable of recognizing its location and adjusting its direction in response to an obstacle, by a vision camera and a vision board. A series patent started from US6496754 (Fig.4), filed 2001, using a vision camera directed toward the ceiling of a room and a vision board, the vision camera recognized a base mark (for example a lamp) on the ceiling. After one year, US6732826, a robot using wireless communications an upwardly-looking camera for photographing an upper image perpendicular to a forward-looking direction of driving the robot cleaner, optional features include second forwardly directed camera to provide a three dimensional image sensors for sensing walls or obstacles and transmission of data to external controllers by a radio antenna.
Remote control patents shown in US7343221, a control system including a signal transmitting unit wirelessly transmits reference signals, the robot performs cleaning in accordance to the received signals. US7526362 is a remote control using a 3-D pointing procedure, controlled in response to a user’s gesture or sign, calculating position of robot in the navigation frame.

In 2005, gyro sensor and grid map were brought up. US7239105 is a method of compensating a gyro sensor, changing to a compensation mode if a robot travels greater than a compensation reference, and compensating an output value of the gyro sensor by use of an upper camera. US7953551 is a method of moving in a minimum cost path using a grid map (Fig.5), planning the minimum cost path from the movement path by selecting one or more shortest-distance via points from the via points. US7996126 using a task manager generating data usable to move the robot along a trajectory of a preset target illumination intensity where the illumination intensity measured by the photosensitive sensor processor is the same as the target illumination intensity.
In 2007, another grid map patent introduced in US7916931, forming a grid map by using a plurality of grid points that are obtained by detecting distances of a mobile robot from obstacles. US8195331 modified the grid map to coarse map, a coarse map generation unit to generate a coarse map composed of a plurality of cells, a fine map generation unit to generate a fine map composed of a plurality of sub-cells. US8463436 introduced further a feature-map-creating unit for recognizing the position of a robot. Further application of grid map is US8463018 and US8352075.

In the technical fields of location recognition, Samsung filed a series patent on camera and remote control, control software focused on how to stored rout or areas, and determining movement path by grid map. It is not convenient to set up a landmark on the ceiling of a family room and difficult to commercialize.

3.2 IRobot utilized barrier signals as a virtual wall

IRobot was interested in barrier signal dividing the cleaning area, different from camera recognizing location and grip map. The navigation control algorithm can be simplified under the confinement.

The basic patent is US6690134, shown in Fig.6 and filed in 2002, includes a portable barrier signal transmitter produces a barrier signal in an infrared frequency, a mobile robot capable of turning in a direction upon detection of the barrier signal. In 2003, two beams transmitter in 6781338, if operation of the mobile robot causes the reflected portion of the first beam to be blocked such that the signal detector fails to detect the reflected portion of the first beam, the second beam can be detected by the robot detector. US6965209 is similar to ‘338, a robot having a propulsion element, a controller, operable to control the propulsion elements and responsive to detection the second beam to control the propulsion elements to move the robot to avoid the second beam. The transmitter improved further to one or more directed beams, each having a predetermined emission pattern, the receiving subsystem is configured and operative to process the one or more detected directed beams under the control of the navigational control algorithm. US7196487 is a processor recognizes the confinement light beam, the processor controls the motor drive to turn the robot in a direction decided according to gradient levels of the confinement light at different orientations of the robot.
US7706917, filed in 2005, is a stationary emitter emitting at least one signal to ceiling, instead of portable emitter, the photodiodes are angularly spaced to face in different directions about the receiver so as to detect one or both of the reflected signals in various positions within the working area. US7188000 improved each directed beam having a predetermined emission pattern, a receiving subsystem functioning as a base station that includes a navigation control algorithm that defines a predetermined triggering event for navigational control system, a reception of the control signal by the robotic device causes the robotic device to implement a prescribed conduct that alters the movement activity of the robotic device.

US7579803, filed in 2007, improved the detector, which can receive confinement light beams substantially in a plane at the height of the field of view while blocking or rejecting confinement light beams substantially above or substantially below the plane at the height of the field of view.
The portable barrier signal transmitter has been commercialized; it is more convenient than camera recognition for family use. IRobot strengthened practical functions of barrier signal and got a series patent. It should say that IRobot takes the lead of this subsystem.

4. Cleaning tools- brush and vacuum system

A broom and a vacuum cleaner are common cleaning tools in family. An autonomous cleaning robot needs a brush for sweeping and vacuum cleaner for collecting dusts at least, and put them in a very compact volume. The major task for R&D is structure design, and ‘automated’ for different surface, carpet or floor, different situation of dirty, without human determination.

4.1 IRobot monopolizes the side brush and flapper brush

IRobot combined two fundamental brushes, main brush and flapper brush, to be brooms of the cleaning robot, as shown in US6883201 (Fig.8), filed 2002. Brushes and suction head of vacuum cleaner are under the robot to get in touch floor in working. Main brush and flapper brush loses the area outside the envelope of the robot, side brush can do this work, it is simple but useful in cleaning, especially edges of wall, which the other robots can’t. IRobot filed a series improvement followed ‘201 patent, and emphasize the side brush again. US7571511, filed 2004, brought up a self-adjusting cleaning head subsystem, which includes a dual-stage brush assembly having counter-rotating, asymmetric brushes and an adjacent, but independent, vacuum assembly.

![Fig.8 Brushes in US6883201 (main brush 94, flapper brush 92, side brush 76)](image)

A side brush is not a new idea, it was used in road cleaning machine at the edges of a sidewalk for decades. This application was rejected by Japan Patent Office, iRobot narrowed claims to distinguish with prior arts, in order to overcome rejection.
Flapper brush is also important, it can scrape something adhere on floor, but easy to stasis due to something. IRobot did their efforts on flapper brush and filed a series of patent. US8087117 is a compliant flap extending radial outward from the core to sweep a floor surface as the roller is driven to rotate, the flap configured to prevent errant filaments from spooling tightly about the core to aid subsequent removal of the filaments; and axial end guards mounted on the core adjacent the ends of the outer core surface and configured to prevent spooled filaments from traversing axially from the outer core surface onto the mounting features, end guard is removable from each longitudinal end of the core.

US7448113, filed 2007, a cleaning head including a deck mounted to pivot with respect to the housing, and a deck adjusting assembly mounted in combination with the deck and the housing that provides lift to the deck, the lift balanced to respond to an increase in brush torque to lift the deck with respect to the housing or floor. US7636982 improved dual-stage brush further, a cleaning head including a dual-stage brush assembly comprising first and second asymmetric brushes mounted in combination with the deck, the second brush having a greater diameter, and a dust collection bin for collecting particulates swept up by the brush assembly, the first brush is positioned to not contact the hard floor surface but to redirect debris from the second brush into the dust collection bin, the first and second asymmetric brushes are counter-rotating.

4.2 Samsung devoted to adjustable brush and air cleaning

Samsung filed a robot cleaner with adjustable brush in 2003 and granted as US7200892, a pivotal brush prevents overload to a suction motor caused by excessive contact of the brush with the floor surface to be cleaned.

US7108731, filed in 2004, is an air cleaning robot, not a floor cleaning one. This patent basically put an air cleaning part disposed in a robot body, for drawing-in air from an open intake, filtering the atmospheric air, and discharging cleaned air into the atmosphere.

US7749294 is also an air cleaning robot, filed in 2006, Samsung put the cyclone structure, could overcome the limited suction efficiency of the small-size suction motor, into a robot cleaner, and separate the dust from the air by centrifugal force.

Edge cleaning function is necessary for cleaning robot, but IRobot occupies side brush, Samsung designed a suction channel instead of a side brush outside the envelope of the robot. US7673367 called it a corner cleaning unit. The corner cleaning unit includes a suction member having a suction arm with a rotatable cylinder, a movable member coupled around the rotatable cylinder by a torsion spring such that the movable member can move upwards and downwards together with the suction member.

4.3 IRobot succeeded in debris cleaning

Debris is not easy to clean since limited suction head and garbage space in a cleaning robot. IRobot filed a series of patent for debris cleaning. Stared at 2004, US6956348, a piezoelectric debris sensor and
associated signal processor responsive to debris strikes to detect the presence of debris and in response, to select a behavioral mode, enable the robot to steer in the direction of debris. In US7288912, a spiraling pattern of movement having a changing turn radius, to substantially immediately cover an area containing debris corresponding to the debris signal. In US8253368, the processor implements a high power cleaning mode in response to the debris signal. In US8456125, including a cleaning head system configured to move debris from the cleaning surface toward the receptacle; a first and a second debris sensing element, each debris sensing element carried by the chassis and arranged to detect the debris moved toward the receptacle, each debris sensing element being within the chassis and proximate the other debris sensing element.

US8476861, shown in Fig.9, is a control module coupled to the piezoelectric sensor and configured control the drive system based on the detected impact of the particulates moving from the side brush to the main brush toward the debris bin.

Fig.9 Debris cleaning structure in US8476861 (piezoelectric debris sensor 125, debris 127, flapper brush 92, main brush 94)

4.4 IRobot leads in wet cleaning

Wet cleaning is more powerful than dry cleaning for special dirty area. Wet cleaning function in a compact robot is difficult, but iRobot successful got a series patents. The fundamental design can be illustrated in US8387193, granted at Mar, 5, 2013.

The robot chassis carries dry and wet cleaning zone, the dry cleaning zone comprising cleaning elements to suction loose particulates up from the cleaning surface, the wet cleaning zone comprising cleaning elements arraigned to apply a cleaning fluid onto the surface and to thereafter collect the cleaning fluid up from the surface after it has been used to clean the surface. The robot chassis carries a supply of cleaning fluid and a waste container for storing waste materials collected up from the cleaning surface. The liquid applicator housed in the robot body and configured to dispense a liquid onto the cleaning surface while the
robot is moving in a direction of forward travel of the robot and suspend dispersion of the liquid while moving in a reverse direction of forward travel of the robot. A scrubber housed in the robot body and engaging the cleaning surface will take the function of a wet mop or sponge attached to the end of a handle manually.

5. Cleaning modes and obstacle avoidance

Many obstacles are in a room, walls, cliffs, furniture, electric appliances, miscellaneous articles, etc. The function of obstacle avoidance may decide the value of the whole robot. The dirty situation in a room is always different in different area. Offering many cleaning mode of a robot for users is necessary, this demands need complicated sensors and controlling software.

5.1 IRobot constructed complete cleaning modes

IRobot divided cleaning mode into two basic types, one is coverage behaviors, the other is escape behaviors, and got a series patents, the first is US6809490(Fig.10), the latest granted is US8463438 on June,11, 2013.

![Cleaning modes in US6809490](image)

Coverage Behaviors include Spot Coverage, Wall/Obstacle Following, and room Coverage.

Spot coverage or spot cleaning allows the user to clean an isolated dirty area. A user places the robot on the floor near the center of the area, the method of achieving spot cleaning is a control algorithm providing spiral behavior. In general, spiral movement is generated by increasing the turning radius as a function of time, or inward such that the radius of the turns continues to decrease.

Wall/Obstacle Following designed for edge cleaning, allows the user to clean only the edges of a room or the edges of objects. The edge-cleaning operational mode let the robot move in such a way that it follows the edge and cleans all areas brought into contact with the cleaning head of the robot. When the robot is placed in
the proximity of an obstacle, it can follow the edge of the obstacle indefinitely and move around obstacle. This mode is powerful for cleaning the area around a leg (obstacle) of a table or a chair.

In the room coverage mode, the method of performing the room cleaning behavior is a BOUNCE behavior in combination with the STRAIGHT LINE behavior. Escape behaviors include four escape situations, various sensors are used to detect these situations.

Situation 1, the robot detects a situation where it might get stuck—for example, a high spot in a carpet or near a lamp base that acts like a ramp for the robot. The robot performs small "panic" turn behaviors to get out of the situation.

Situation 2, the robot is physically stuck—for example, the robot is wedged under a couch or against a wall, tangled in cords or carpet tassels, or stuck on a pile of electrical cords with its wheels spinning. The robot performs large panic turn behaviors and turns off relevant motors to escape from the obstruction.

Situation 3, the robot is in a small, confined area—for example, the robot is between the legs of a chair or in the open area under a dresser, or in a small area created by placing a lamp close to the corner of a room. The robot edge follows using its bumper and/or performs panic turn behaviors to escape from the area.

Situation 4, the robot has been stuck and cannot free itself, the robot stops operation and signals to the user for help. This preserves battery life and prevents damage to floors or furniture.

The robot has four escape behaviors: turn, edge, wheel drop and slow. Turn means the robot turns in place in a random direction. Edge means the robot follows the edge using its bump sensor. Wheel drop lets the robot back drive wheels briefly, and then stops them. If a wheel drop or a cliff detector goes off, the robot slows down to speed of 77% of its normal speed for a distance of 0.5m and then ramps back up to its normal speed.

5.2 IRobot designed for various obstacles

IRobot invented two obstacle detection modes by emitter in US6594844. One mode having an optical emitter which emits a directed beam having a defined field of emission, and a photon detector having a defined field of view which intersects the field of emission of the emitter at a finite region, detector can detect obstacles in the field of emission, and redirecting the robot to avoid obstacles. The other mode is wall detection system, includes a housing which navigates with respect to a wall, and a sensor subsystem having a defined relationship with respect to the housing and aimed at the wall for detecting the presence of the wall, and redirects the robot when the wall occupies the region.

US7155308 filed in 2003 and followed the first mode, comprising at least two emitters and two photon detectors. US7430455 filed in 2007 and followed the second mode, a circular robot housing, a drive system housed by the robot housing and configured to maneuver the robot with respect to a wall.

5.3 Samsung developed wall-following mode
In obstacle avoidance, Samsung utilized camera again, US6496754 not only including a vision camera directed toward the ceiling, but also obstacle detecting devices, which includes a line laser for emitting a linear light beam toward the obstacle, and a second vision camera for recognizing a reflective linear light beam from the obstacle.

US7213663 is a robot with a shock-absorbing unit, includes a pair of driven wheels following the pair of driving wheels. In US8457789, introduced a wall-following technique allows the robot to travel along the outline of the cleaning region. US8209053 is a bumper unit, and control unit controls the driving unit on the basis of a signal sensed by the sensor to avoid the obstacle. US8346389 is a robot having a carpet detector to detect the carpet and its boundary. All these techniques are not special in autonomous robots.

6. Energy management and Docking

An automated cleaning robot uses recharge battery as power, the recharging system needs automated, too. How to let the robot come home and reconnect to an external recharging device is important. Energy management can reduce recharging times.

6.1 Samsung used photographed image for recharging

The fundamental recharging system started at US6957712 (Fig.11), filed in 2002, a robot cleaner capable of returning to an external recharging device. Samsung used a camera again for photographing external surroundings for recognition of a connection position where the external recharging device is connected with the robot cleaner and stores the photographed image. Returning of the robot cleaner is carried out when the robot completes its job or needs a recharging, by using the previously stored image and an image currently taken by the camera.

Fig.11 recharging system shown in US69577412,
(robot cleaner 10, front camera 13, seating portion 33, supply terminals 31)
How to decrease an error in the location process is important for recharging. US6748297, filed in 2003, brought up a robot cleaner system capable of accurately docking with an external charging apparatus. The robot cleaner photographs an upward-looking image using the upper camera, calculates location information of the external charging apparatus, and stores it. When returning to the external charging apparatus, the robot cleaner calculates a return path.

US7031805 having a recognition mark sensor that detects the recharging apparatus recognition mark. The robot cleaner automatically docks to the power terminal by recognition mark, made of a metal tape.

US7417404, filed in 2004, has a recharging terminal to which a battery terminal of the robot cleaner is docked and an anchor member on a rear side of the body of the recharging unit. The anchor member fills in the space defined between the wall of the room and the power recharger. The anchor member therefore securely supports the power recharger in the battery recharging process.

6.2 IRobot used emitter to come home

US7332890, filed in 2004, is a method for energy management in a robotic device includes providing a base station for mating with the robotic device, determining a quantity of energy stored in an energy storage unit of the robotic device, and performing a predetermined task based at least in part on the quantity of energy stored. Also disclosed are systems for emitting avoidance signals to prevent inadvertent contact between the robot and the base station, and systems for emitting homing signals to allow the robotic device to accurately dock with the base station.

6.3 Samsung turned to transmitter and dust remover after 2005

Samsung and IRobot developed different type of docking for recharging system. Samsung changed their system from photographed to transmitter in 2005, US7489985, a plurality of transmission parts for sending signals having different codes and strengths; a robot cleaner including a receiving part for receiving signals, so that the connection terminal is connected to the charging terminal.

Samsung developed the docking station more functions, for example, dust collector. US7849555, filed in 2006, a system capable of moving a first dust collector mounted in a robot cleaner to a docking station to remove dust collected in the first dust collector. In 2007, an improved docking structure was filed, US7861366 is a system capable of an easy docking operation of the robot cleaner and preventing loss of a suction force generated in the docking station, a protrusion communicates a dust discharge hole of the robot cleaner with the dust suction path of the docking station.

7. Conclusions

A search queries in patent database can obtain an overview for a technical topic quickly. Samsung leads in patent numbers of cleaning robots, both applications and granted. We can’t deduce a conclusion that
Samsung leading in the technical fields in cleaning robot because unequal value of patents.

It needs labor and time to view patent document one by one. A bubble map is helpful to read patent description efficiently, can be a bridge from macroscopic to microscopic view. We made classification depends on the top two patentees, the reason is they may predominant the standardization. The other patentees can show on the same bubble map easily.

Samsung leads in camera photographing and remote control though, iRobot put their remote control technology in robot vehicles, not home robots and not shown in Fig.3. iRobot is not necessary weaker in remote control. iRobot accumulated series patents in barrier signal as virtual wall and get the leading position.

In the cleaning tools, iRobot is strong in brush, wet and dry cleaning, debris detecting and collecting, all of these are important for an automated robot. Samsung developed some patents for vacuum suction, not special in robot and difficult to put into a compact robot. iRobot hasn’t got any patent in vacuum suction, but strengthened this subsystem by acquiring Evolution Robotics, which owns 6 granted patents in this subsystem.

iRobot also takes lead in cleaning mode and obstacle avoidance. It is interesting that coverage and escape behaviors are powerful in cleaning, especially under tables, chairs, cabinets, or beds, which are inconvenient to clean by human being.

In view of operational manual of Roomba, main product of iRobot, we can find that more than 80% functions of iRobot’s patents has been commercialized, it’s a great hurdle and difficult to overcome because of exclusive rights. After microscopic analysis of patent and pay attention to functions of user’s demands, we should say that iRobot not only leads in this technical fields but is also far ahead Samsung.

Macroscopic analysis of patents is useful tools to make an overview for designated technical topics but may misconstrue patent value. Microscopic point of view can understand technical value and development of each patent but need labors and time. Applying both methods alternately and using a bubble map to be a bridge can get precise results.

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