

## RELATION BETWEEN FUNCTION AND FORM IN VACUUM CLEANERS DESIGN

**Abstract:** The paper analyses how robotic vacuum cleaner works, describing their cleaning capabilities and additional features. The paper illustrates advantages of using robotic vacuum cleaners that have intelligent programming and a vacuum cleaning system, the components of a robotic vacuum cleaner. The paper develops aspects concerning to create 2D scale models for the evaluation of specific features of the new components for a prototype robotic vacuum cleaner.

**Key words:** robotic vacuum cleaner, components, characteristic, form, prototype.

### 1. INTRODUCTION

The houses from our days are becoming smarter and more automated. Home automation is needed because it delivers convenience and it creates more time for people by minimizing the effort required to accomplish their jobs. Domestic robots industry starts in early 80 and make its presence felt increasingly in homes and lives of people, but it is yet relatively new in market. However, although people were reticent at first, their thinking have performed in time and robots have started to adapt to the needs of our times. The project is to design a conceptual solution for a domestic cleaning robot that vacuum cleans, wet cleans the floors and also can perform the function of air purifier. The system requires to:

- remove dust from the floor;
- clean the floor with clean water;
- remove dirt water and leave as dry as possible;
- clean the air from the room.

### 2. HOW IT WORKS?

To know what happens in a vacuum we must understand the mechanism of vacuum cleaners. It can be explained with sipping soda out of a straw. The sipping creates a pressure difference between the bottom and the top of the straw and the fluid is “pushed” from the high-pressure area to the low-pressure area. Vacuum cleaners work in the same manner, since the particles are being suctioned due to the pressure difference.

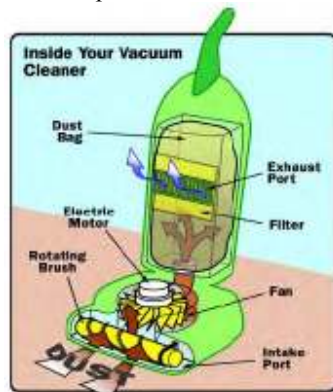


Fig. 1 Components of vacuum cleaner [3]

Components of a vacuum cleaner are: an intake port, an exhaust port, an electric motor, a fan, a filter and a dust compartment (see Fig. 1). When the motor that is attached to the fan creates the wanted pressure drop at the exhaust port the ambient air is pushed into the vacuum cleaner through the intake port and the particles are suctioned into the dust compartment. The filter contains holes, which are small enough to stop the particles, but large enough to let the air go through. The dirty air is filtered and flows through the exhaust port. What determines the suction power is the power of the fan, the shape of the air passageway and the size of the intake port's opening [2].

The other process that we need to understand is how air cleaners work. Air-purifiers are devices that clean and filter the air. It helps in air-purification by freeing the air from all types of pollutants and contaminants. Air purifiers are basically used in the hospitals, work sites and homes to protect people against suffering from pollen, pet dander, tobacco smoke, dust mites, viruses, molds and bacteria. The different components of air-purifiers include electrostatic filters, ozone generators, HEPA [High efficiency Particulate Air] filters, ion generators, ultraviolet light and various other modern methods to get rid of both large and miniscule particles (see Fig. 2).

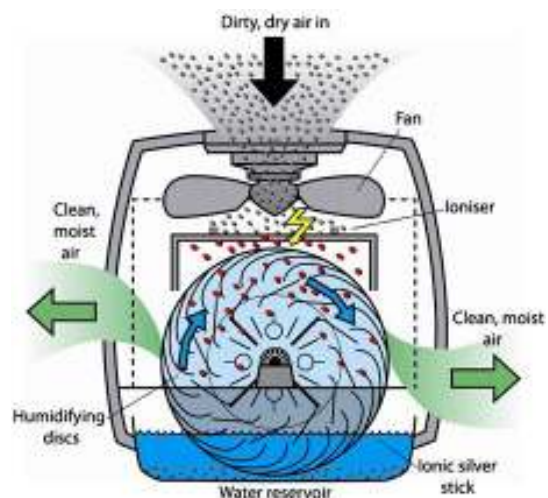


Fig. 2 Inside of air purifier [7]

The dirty air is absorbed in by a fan, passed through a moistened filter so that all dust particles remain blocked, and moist clean air escapes through side openings.

The robotic vacuum cleaners aim to achieve vacuum cleaning with minimal human interaction. The cleaners operate with the same suction system as regular vacuum cleaners but in order to avoid the human interaction a self-navigation system is required. By pressing of button start or a pre-scheduling feature the cleaning robot operate through the room. The robots conventionally start their cleaning route by mapping the room to obtain the room size, either with an infrared signal or with a laser scanner. Algorithms that determine the cleaning path make them run in arbitrary patterns to finally ensure full coverage. However, some of cleaners works more systematically and creates a square of the room and operates methodically within the square [1].

During the cleaning cycle the robots recognize obstacles with bumpers in the front or by the newest method to prevent collision with obstacles using acoustic waves (Sharp Cocorobo). In Fig. 3 you can see same models of robotic vacuum cleaners from the market.



**Fig. 3** Robotic vacuum cleaners.  
(Sharp Cocorobo, Lg VR6260LVM, IRobot Roomba 880)

The particle suction is enhanced through using one or more brushes. Usually, the cleaning robots carry a roller brush. However, several also have side brushes to enhance corner and edge cleaning. Most of robotic vacuum cleaner has one side brush one the right side, which is the side that is programed to follow edges. Most of the cleaners have cliff sensors that prevent them from falling from heights, such as stairs. The user can also place virtual walls in the home to prevent it from entering unwanted areas.

The robots are powered by rechargeable batteries whose capacity determines the cleaning time. If the desired cleaning area is not finished within the battery time they return to their base station to recharge and afterwards the robot continues the cleaning where it stopped.

The low height of the robots increases the mobility and accessibility for them so they are able to cover larger areas. They can access areas which classic vacuum cleans usually can't, like the space under furniture in order to clean all the dust from there.

The design of these robotic vacuum cleaners is one of the simplest as their usual form represents a circle, with the diameter smaller than 40 centimeters. The front wheel allows the robot to rotate around its center and the side wheels only have the purpose to push forward the machine.

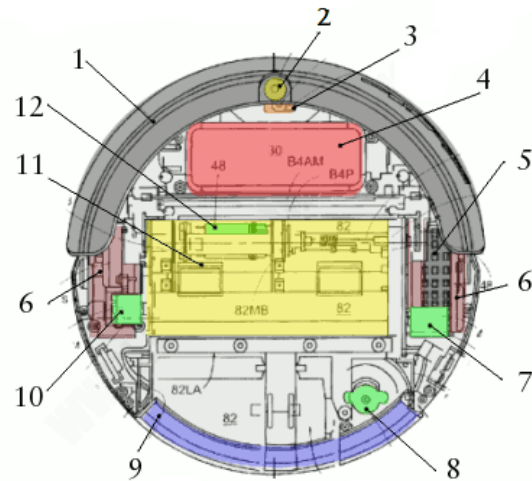
Main components that can be seen on the back of the vacuum cleaner are presented in figure 4.



**Fig. 4** Side of robotic vacuum cleaner (iRobot)

Other features the cleaners carry are UV-light to disinfect or dirt detection sensors to enhance the cleaning. Some can even empty the dustbin at the base station automatically. All of this is to ensure minimal involvement by the user. Nevertheless, regarding cleaning performance the robotic vacuum cleaners have not advanced enough to replace regular vacuum cleaners yet [8].

The detailed components of a robotic vacuum cleaner are (see Fig. 5):



**Fig. 5** Components of robotic vacuum cleaner [5]

1. Obstacle detection bumper;
2. Infrared detector;
3. Wheel drop sensor;
4. Lithium metal-hydride rechargeable battery pack;
5. Wheels which provide extra traction on smooth floors and help to prevent tufts from carpets and rugs snagging;
6. Wheel assembly;
7. Electric motor wheel;
8. Electric motor for the vacuum system;
9. Removable dust bin;
10. Electric motor for left wheel;
11. Brush mechanism;
12. Electric motor for the brushes.

### 3. ARE ANY ADVANTAGES OF USING ROBOTIC VACCUM CLEANERS? [9]

- Help's people with mobility problems - They need to clean their homes by contracting housekeeping services, that is expensive so it's better to buy a robotic vacuum cleaner, and the investing will be recovered in time. Also the robot can be set to clean as often as required, while minimal maintenance is need.
- It's small so that will give him same advantages to enter under furniture - Disk shape help's to protect the furniture or other object and also gives maneuverability and flexibility. It can be any ware in the room, on all corners or undersides of furniture, that it's a great think witch the classic vacuum cleaners can't be done.
- Can set-up him to clean the house when you aren't at home - When you are at work or at the shopping, you can setup the robotic vacuum cleaner to clean your house as well. So noise you usually hear from a classic cleaner will disappear.
- He can protect himself from auto breaking or destroying - A robotic vacuum cleaner can detect changes in the surface so it will auto adjust its settings accordingly. It can also detect walls and stairs and will automatically turn around when it comes across one.
- Automatic recharging option it's available - Once the robotic vacuum cleaner finish his job or it's running low on battery, it will go back to its docking station.
- Help's you to save time. Most families of our days consist of working parents and one or more kids. In such case, cleaning is a waste of time and an exhausting task, especially when you have a big house. So the time that you use before to clean the house, now can be spend by doing what you want.
- You can use virtual walls for making a boundary that the robot will not cross. It is ideal to prevent the machine from going across doorways and openings.
- Maintenance is not required - A robotic cleaner is a machine that will last for years if you treated him properly. You need to clean the dust bag as needed and clean the filter and brushes, no other maintenance need to be done.
- Detects dirty from the floor – Robotic cleaners have a lot of sensor that can detect places where existing dirty. The machine will cross that location repeatedly until the surface it is clean.

### 4. ROBOTIC VACUUM CLEANERS MARKET ANALYSIS

So it is good to know production companies of robot vacuum cleaners which are the most important (table 1). For making a parallel between qualities of cleaning robots we need to consider different technical details like: cleaning performance, battery life, noise level, price and others. These technical details were placed in a product comparison chart to have the ability to easily compare the different products available on the market.

The main manufacturers of robot vacuums are:

- IRobot

- Moneual
- Karcher
- Vorwerk

Table 1

Overview of the main competitors

Company	IRobot	Moneual	Karcher	Vorwerk
Country	SUA	Korean	Germany	Germany
Sales Revenue (€)	487.4 million	1 million	1.92 billion	2.367 billion
Employees	528	<500	>10000	12545
Founded	1990	2001	1935	1883

The cleaning robots compete in a wide range of diverse features like design, ease of use, experience in use, reliability and quality. The main constraint that must be regarded in the development of a cleaning robot is the size, since without a minimal size it will not maintain its mobility. While sustaining the small size the robot must deliver a proper cleaning result with minimal human intervention.

The latest addition in terms of robot vacuum cleaner is IRobot Scooba 450 that has both the opportunity washing and dry cleaning, operation being done in 4 stages (Fig. 6).

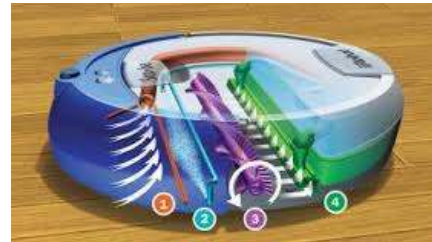


Fig. 6 IRobot Scooba 4 stages cleaning process [4]

The following charts show a summary of 4 vacuum cleaners technical characteristics [6] from the companies presented above:

1. IRobot Scooba 450
2. Moneual Rydis H68
3. Karcher RC3000
4. Vorwerk Kobold VR100

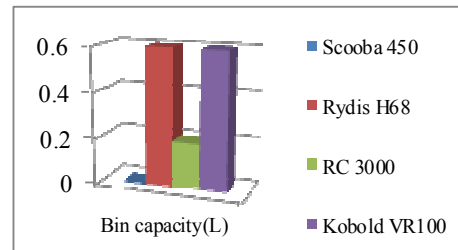


Fig. 7 Comparison between bin capacities of different vacuum cleaners

Considering the bin capacity, the performance increases with it and it is clear that the Kobold model has the highest number of liters meaning almost 0.6 whereas the Scooba model has the lowest capacity. Actually, the IRobot Scooba 450 has a water tank instead of a normal

dust bin, so it can be said that the lowest bin capacity belongs to the RC 3000 model (fig. 7).

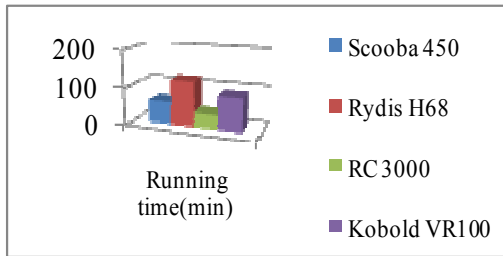


Fig. 8 Parallel between running time of 4 vacuum cleaners

From running time's point of view, Rydis H68 achieves two hours comparing to RC 3000 which has only about 20 minutes. Battery life is influenced not only about the model of the vacuum cleaner's firm but also by the responsibility of the owner as there are a lot of conditions to respect as it functions as a normal battery. It is known that if the battery life is longer, the cleaning will be complete as the robotic vacuum cleaner will pass more than a time on a certain surface (fig. 8).

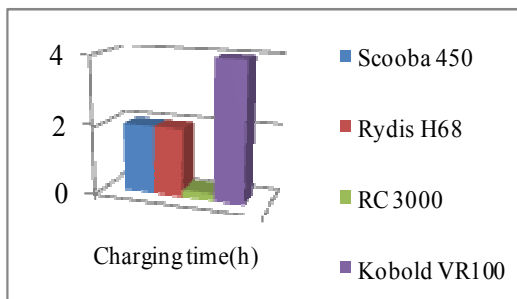


Fig. 9 Charging time of four models

Regarding the charging time, some of the models need about four hours to charge like Kobold VR100 and others need just 40 minutes to be able start cleaning like RC 3000 (fig. 9). The Scooba 450 model and Rydis H68 require two hours of charging which is not that much, but it is important to have a minimum of charging time as the electricity bill seems to get bigger each day.

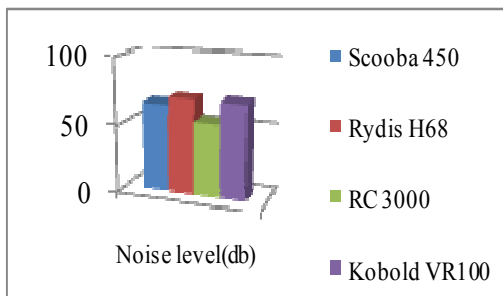


Fig. 10 Noise level at four robotic vacuum cleaners

Everyone has had at least once in a lifetime a vacuum cleaner which could be heard by their neighbors. But somehow, the noise level at robotic vacuum cleaner is much smaller, achieving from these four models the maximum of 70 db which is close to the noise made by a

conversation (fig. 10). Noise level is important because it can affect people's routine life and it is easily to work in silence and meanwhile the cleaning is maintained. So, the smaller is the noise, the better the atmosphere.

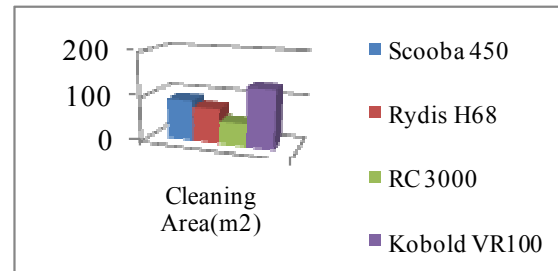


Fig. 11 Cleaning area of different vacuum cleaners

Cleaning area depends directly on the battery time, but there are chances to clean a surface twice if the robotic vacuum cleaner still has battery. The Kobold VR100 model can achieve over 100 square meters even if it does not have the longest running time, meaning that is more effective than the others. The smaller cleaning area is RC 3000 model's meaning approximately 50 square meters (fig. 11).

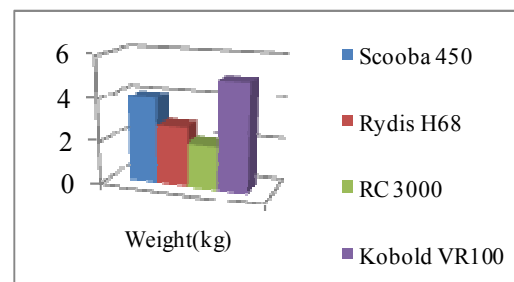


Fig. 12 Cleaners' weight

The cleaners' weight depends on a lot of different characteristics like battery, water tank, motion system and number of brushes, but still, people will be influenced to buy the slightest robotic vacuum cleaner. One of these is RC 3000 which has only two kilograms whereas Kobold VR100 has over four kilos (fig. 12).

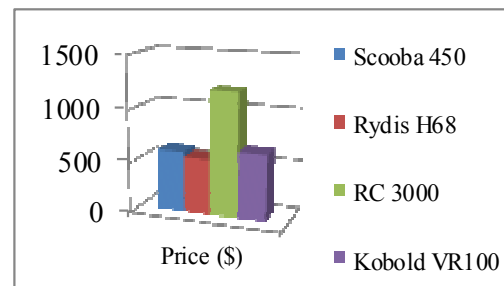


Fig. 13 Comparison between prices of robotic vacuum cleaners

All people want a lower price for the products described just that they are still at its beginning and robot vacuum cleaners on the market is not high competition so prices are still high. The highest price is RC 3000 model's but it can be easily reasoned because the robotic



vacuum cleaner has the possibility to communicate with its own station of charging as many times as it is necessary (fig. 13). Also, the station has many functions as empty the dust bin.

The following analysis we did to see a comparison of features that vacuums incorporates them and also the dimensions of cleaners (See table 2).

Table 2

Features of robotic vacuum cleaners				
Technical Details	Scooba 450	Rydis H68	RC 3000	Kobold VR100
Automatic Charging	Yes (optional)	Yes	Yes	Yes
Climb Obstacles	No	No	Yes	Yes
Smartphone connectivity	No	No	No	No
Dirt Detection	No	No	Yes	Yes
HEPA-Filters	No	No	Yes	No
Water cleaning	Yes	Yes	No	No
Scheduled Cleaning	No	Yes	No	Yes
Dimensions (mm)	366φ	381φ	285x105	330x318

These features make the difference between the present models and they can influence people on making a decision of buying one. For instance, the automatic charging is a benefit as people do not have to worry about the battery which is 'running out' as they already do about their other gadgets. In the case of these four robotic vacuum cleaners, it is present at each of them but optional for Scooba 450. Some of these cleaners meaning RC 3000 and Kobold VR100 can climb obstacles, which can be a pro and a con at the same time: the robots will clean carpets, but also they can take unwanted objects like keys and it will damage the inside of the cleaner. Even though none of these models have smartphone connectivity, there are other cleaners which have this feature like Sharp Cocorobo.

Another important feature that RC 3000 and Kobold VR100 have is dirt detection, which will decrease the time to clean a certain area and also the surface in order to get immaculate. RC 3000 has HEPA-filters, which is a type of an air filter which can hold 99.97% of particles that have a size of 0.3  $\mu\text{m}$ . Water cleaning is a feature present on Scooba 450 and Rydis H68. It is a new 'must' to have a robotic vacuum cleaner with this feature as people will no longer have to wash their floors. Also, some vacuum cleaners like Rydis H68 and Kobold VR100 can be scheduled to do the cleaning in the time the owner is at work and, in this way, people won't be bothered anymore by the noise the robots produce.

## 5. CASE STUDY

It is about a robotic vacuum cleaner that should fulfil the next tasks: remove dusts from the floor, clean the floor with clean water, remove the water and leave the floor as dry as possible and clean the air from the room.

To make all of these possible in small dimensions we must take into account the possibility of attaching new modules at the back of robotic vacuum cleaner.

The new system will include the following models:

1. The main part consists in skin, motion system, dust bin, engine for vacuum, brushes, acoustic sensors for avoiding obstacles, laser sensors in the bottom for avoiding stairs, on the front sensor for scanning the room and the battery (fig. 14).

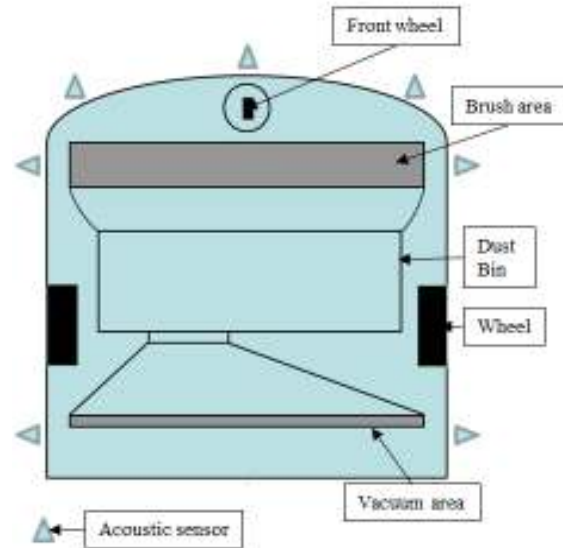


Fig. 14 Main part of robotic vacuum cleaner

2. Second module will be made for making the wet cleaning, he consist of skin, water tank split in two parts: one part for clean water and one for the dirty water, a drip system which has the function of leaving drops of water on the floor and a vacuum water absorber for leaving the floor dry and clean behind the cleaner (fig. 15).

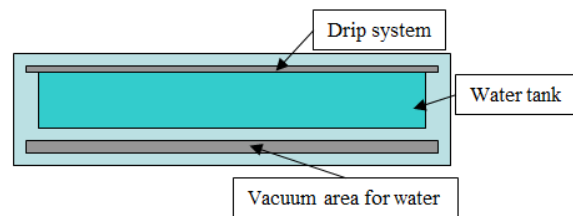


Fig. 15 Second module for water cleaning

3. The last module of robotic vacuum cleaner will be used for cleaning the air from the room. This will have the same principle like an air purifier, can be used any time of day, noise that will be heard is lesser than laptop in use. Also can be used when the robot is connected to docking station. He consists of skin, two fans, water tank and a HEPA filter (fig. 16).

These modules will be attached at the back of main part through rails system that will make easier to switch wet cleaning tool or air purifier. Catching will be achieved through a rails system which also will send the

current in order to power the secondary modules (See in fig. 17).

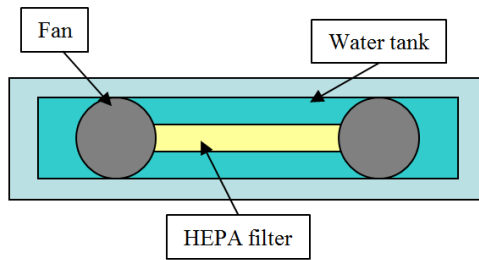


Fig. 16 Third module for air purifier

This vacuum cleaner can be also used without having attached modules; in that case it can do the job of a classic vacuum cleaner with brush and vacuum for dust.

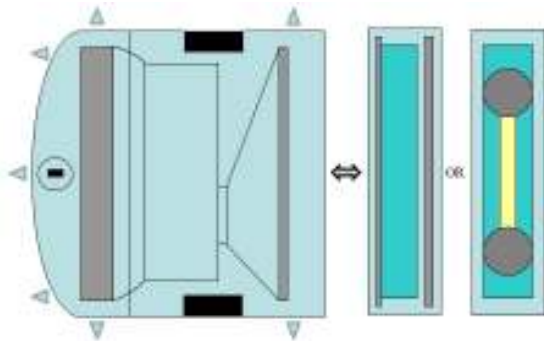


Fig. 17 How you can assembly the cleaner

## 6. CONCLUSIONS

Vacuums are indispensable in people's households, it helps us to save time, and we can make the cleaning more efficiently.

The new range of robotic vacuum cleaners is the devices that have more features. Besides the classic function of normal vacuuming dust it can clean and apply liquid detergent on the floor and now function of an air purifier. If any device could perform multiple functions at the same time it means that we'll take up less space in the house with them.

Solution that I suggest fits into current trends to make our job easier, to occupy a smaller space in houses and also it can perform several functions at once.

Market vacuum cleaners robot is in constant development and begins to increasingly its presence more and more, soon of because rules that are imposed on us, classical vacuum will disappear and will be replaced by these small machines.

## REFERENCES

- [1] Gervasi, O., Gavrilova, M.L., Kumar, V. (2005). *Computational Science and Its Applications – ICCSA 2005 Part IV*, Springer, ISSN 0302-9743.
- [2] Plesea, D. A., (1999). *The study of marketable electrical and electronic products (Merceologia produselor electrice si electronice)*, Editor ASE, ISBN 9739462081.
- [3] How Vacuum Cleaners Work. How Stuff Works. <http://home.howstuffworks.com/vacuum-cleaner.html>, (accessed on 2015 - 05)
- [4] iRobot Scooba 450 <http://www.cnet.com/products/irobot-scooba-450/>, (accessed on 2015 - 05)
- [5] Roomba® vacuum cleaning robots <http://www.explainthatstuff.com/how-roomba-works.html>, (accessed on 2015 - 04)
- [6] (accessed on 2015 - 04) Best Robot Vacuums 2015 <http://www.tomsguide.com/us/best-robot-vacuums,review-2000.html>
- [7] (accessed on 2015 - 05) Types of Air Purifiers and Their Benefits <http://www.tidyhouse.info/types-of-air-purifiers-and-their-benefits-584/>
- [8] (accessed on 2015 - 04) Real Robots [http://www.robotbooks.com/robotic\\_lawn\\_mower\\_robot\\_vacuum.html](http://www.robotbooks.com/robotic_lawn_mower_robot_vacuum.html)
- [9] (accessed on 2015 - 05) 12 Advantages of Robot Vacuum Cleaner over Traditional Ones <http://www.mygenie.com.sg/12-advantages-of-robot-vacuum-cleaner-over-traditional-ones/>

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