# INNOVATIVE ANALYSIS

## ROOMBA TANGLES

**TEAM MEMBERS**
JOHN MORGAN
SAMANTHA RINARD
YANNIS FRÖHNER
VILAPHONG VISOURY
PARTH PATEL

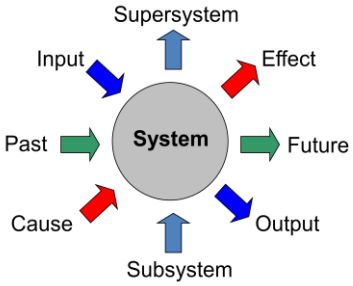
## 1. BRIEF DESCRIPTION OF THE SITUATION

The Roomba is an autonomous vacuum equipped with a number of sensors allowing it to travel across hard and carpeted floors and vacuum up dust and other particles. Dirt is captured into a bin that slides into and out of the body of the vacuum. A rotating bar (pictured here) on the bottom of the unit dislodges dirt and other items from the floor. These loose items are then sucked into the bin. The owner must periodically remove and empty the bin. However, over time, the rotating bar becomes tangled with human and pet hair (also shown here). Long strands of hair tend to wrap around the bar preventing them from being sucked into the bin. Over successive uses, the hair wraps around the bar limiting the effectiveness of the bar. When enough hair becomes entangled on the bar, hair tends to become tangled on other moving parts such as the drive sprockets and wheels. The user must occasionally clean the entangled hair from the bar and other mechanisms. However, doing this is difficult because the hair becomes wrapped tighter and tighter as the Roomba is used over a period of several days. Often, owners must use scissors, pliers, and other tools to cut and loosen the tangle and pull it from the mechanisms piece by piece. This requires 30-60 minutes of work and is most undesirable. One suggestion is to simply replace the rotating bar instead of cleaning it but the replacement bar is a costly item ($13 minimum) so owners are likely to be willing to pay this only once per year.

The goal of this project is to suggest ways to improve this situation. It is expected that you will be able to find ways to either prevent or retard the buildup of the tangle in the first place or find ways to make the cleanup much easier. Perform the systems analysis, then use the I-TRIZ operators to find potential solutions (see section 5 for more details).

## 2. DETAILED DESCRIPTION OF THE SITUATION

### 2.1 SUPERSYTEM/SUBSYSTEM ANALYSIS




1.0 Chassis
- 1.1 Bumper
  - 1.1.1 Wall sensor
  - 1.1.2 Cliff sensor
- 1.2 Handle

2.0 Battery
- 2.1 Charger contacts

3.0 Charger contacts sensor

4.0 Charging station sensor

5.0 Infrared sensor

6.0 Wheels
- 6.1 Front roller
- 6.2 Right wheel
- 6.3 Left wheel

7.0 Control Panel
- 7.1 Buttons
  - 7.1.1 Power button
  - 7.1.2 Regular cleaning button
  - 7.1.3 Max. cleaning button
  - 7.1.4 Dirt bin release button
- 7.2 Lights
  - 7.2.1 Power light
  - 7.2.2 Battery light
  - 7.2.3 Full Bin light

8.0 Dirt bin
- 8.1 Handle

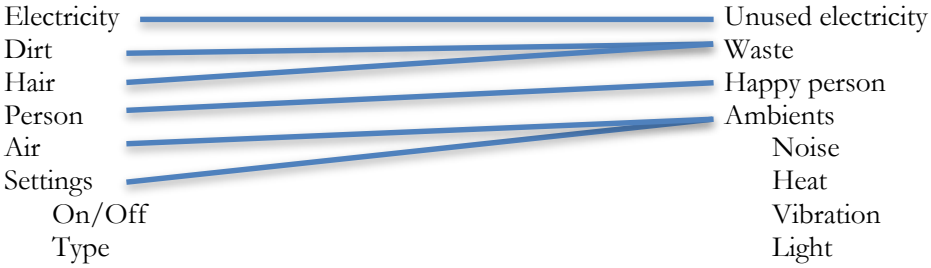
9.0 Beater bar
- 9.1 Bristles

10.0 Side brush

11.0 Motors
- 11.1 Wheel motor
- 11.2 Vacuuming motor
- 11.3 Side brush motor
- 11.4 Beater bar motor

12.0 Computer

### 2.2 INPUT/OUTPUT ANALYSIS



## 2.3 CAUSE/EFFECT ANALYSIS

**Idle**
**Activating**
1.1 Person presses power button on control panel causing computer to activate.
1.2 Person presses regular cleaning intensity button on control panel selecting cleaning type.
**Room-Sensing**
2.1 Computer signals infrared sensor causing infrared sensor to send out infrared signal.
2.2 Infrared sensor checks duration for infrared signal to bounce back causing computer to calculate room size and cleaning duration.
**Vacuuming**
3.1 Computer signals side brush motor causing side brush to spin.
3.2 Computer signals beater bar motor causing beater bar to spin.
3.3 Computer signals wheel motor causing wheels to spin.
3.4 Computer signals vacuuming motor causing vacuuming motor to start vacuuming.
3.5 Vacuuming motor starts vacuuming causing dirt bin to fill.
**Sensing**
4.1 Bumper encounters obstacle causing bumper to retract.
4.2 Bumper retracts causing activation of wall sensor on bumper.
4.3 Wall sensor on bumper signals computer causing wheels to back up and redirect.
4.4 Cliff sensor on bumper senses cliff causing wheels to back up and redirect.
**Returning**
5.1 Battery runs low causing computer to detect need for charging.
5.2 Computer signals charging station sensor to send out signal.
5.3 Charging station sensor acquires signal from charging station causing charging station sensor to signal computer.
5.4 Computer receives signal from charging station sensor causing location of charging station.
5.5 Computer signals wheels making Roomba return to charging station.
5.6 Computer signals vacuuming motor to stop causing vacuuming motor to stop.
5.7 Computer signals side brush motor to stop causing side brush to stop spinning.
5.8 Computer signals beater bar motor to stop causing beater bar to stop spinning.
**Charging**
6.1 Computer signals charger contacts sensor causing charger contacts sensor to sense charger contacts on charging station.
6.2 Computer signals wheel motor to stop at right moment causing charger contacts on battery get in contact with charger contacts on charging station.
6.3 Charger contacts on battery in contact with charger contacts on charging station causes battery to charge.
**Deactivating**
7.1 Person presses power button on control panel causing computer to deactivate.
**Detaching**
8.1 Person grasps handle on chassis and pulls causing Roomba to lift up in the air.
8.2 Person grasps handle on dirt bin and pulls causing dirt bin to reattach from chassis.
**Emptying**
9.1 Person presses dirt bin release button on control panel causing dirt bin to be released.
9.2 Person disposes dirt bin contents causing dirt bin to empty.
**Reattaching**
10.1 Person grasps handle on dirt bin and pushes causing dirt bin to reattach to chassis.
10.2 Person grasps handle on chassis and lowers arm causing Roomba to be back on floor.
**Idle**

## 2.4 PAST/FUTURE ANALYSIS

As of 2016, there have been seven generations of Roomba units: the first-generation Original Series, the second-generation 400 & Discovery Series, the third-generation Professional & 500 Series, the fourth-generation 600 Series, the fifth-generation 700 Series, the sixth-generation 800 Series, and the seventh-generation 980 model. All models have a pair of brushes, rotating in opposite directions, to pick up debris from the floor. Introduced in September 2002, the first-generation Roomba had three buttons for room size. The first-generation units comprise the original, silver-colored Roomba, the blue Roomba Pro, and the maroon Roomba Pro Elite. The latter two models included additional accessories, but all three use the same core robot and cleaning system. The second-generation Roombas ("Discovery", later called 400 series) replaced their predecessors in July 2004, added a larger dust bin, improved software that calculates room size, dirt detection, and fast charging in the home base.

Roomba budget models (Dirt Dog and Model 401) have a simplified interface (a single button) and lack some of the software-controlled flexibility of other versions. They are less expensive for first-time purchasers. The Roomba Dirt Dog contains sweeping brushes and a larger dust bin, but lacks the vacuum motor. It uses the space that would be required for the vacuum for additional dust bin volume. It was designed for a home shop or garage environment. The Dirt Dog was discontinued in 2010. The Roomba Model 401 is similar but has a standard-size dust bin and vacuum system. The third-generation 500 series Roomba was introduced in August 2007 and features a forward-looking infrared sensor to detect obstacles and reduce speed, a dock button, improved mechanical components, smoother operation, and a modular design to facilitate part replacement. It also introduced customizable decorative face plates. The Roomba 530 includes two virtual walls and a recharging dock. The 500 series were superseded by the 600 series since August 2012. 600 series models come with the aerovac bin and advanced cleaning head. The 700 series, introduced in May 2011, though largely like the 500 and 600 series, includes improvements of a more robust cleaning system, improved aerovac bin with HEPA filter and improved battery life. [1]

Like the 500 series, the 700 series includes robots with different technologies and accessories. The Roomba 760 is the simplest of the robots, and Roomba 790 is the second newest and advanced with both scheduling and a large range of accessories including lighthouses, wireless command center and extra brushes and filters. Besides these two models, Roomba 770 and 780 are available, with both scheduling, dirt detect, and full bin indicator.

As for the future, Roombas will begin to have the capabilities such as Bluetooth connection, being summoned to charging station via smartphone, tablet, computer. Through the Roomba application, a user can set clean times, set designated cleaning areas, and adjust suction power. [2]

**Sources**

[1] "Roomba," Wikipedia, Internet page located at https://en.wikipedia.org/wiki/Roomba last accessed on 12/2/16.

[2] "Is this gadget too far," IBTIMES, Internet page located at http://www.ibtimes.co.uk/irobot-roomba-980-review-this-800-robot-vacuum-cleaner-gadget-too-far-1575141 accessed on 12/2/2016.

### 2.5 STATES

1. Idle
2. Activating
3. Room-Sensing
4. Vacuuming
5. Sensing
6. Returning
7. Charging
8. Deactivating
9. Detaching
10. Emptying
11. Reattaching
12. Idle

## 3. RESOURCES, CONSTRAINTS, AND LIMITATIONS

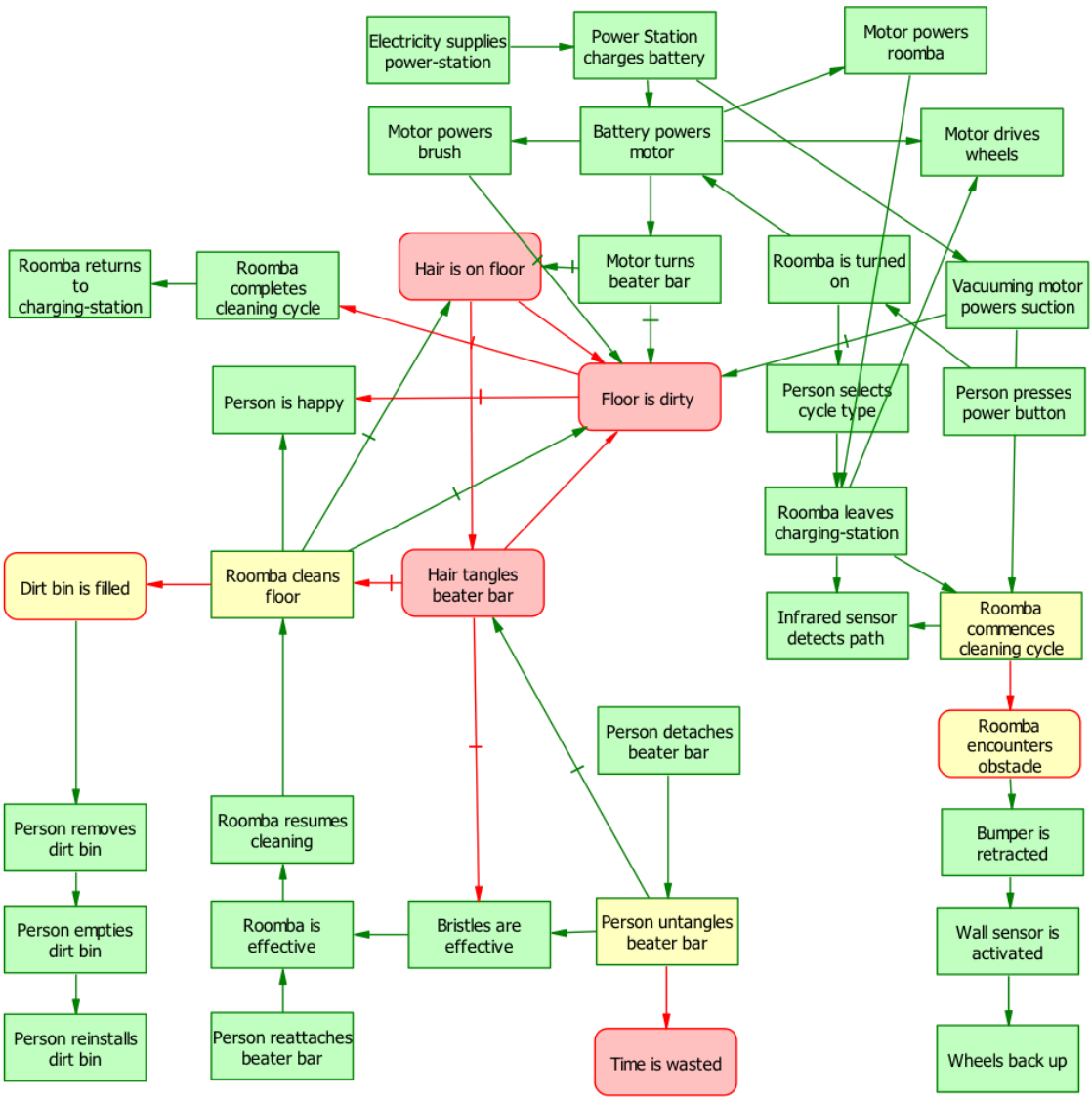
### 3.1 ALLOWABLE CHANGES TO THE SYSTEM

- Your solution may include changes to the rotating bar or any other standard attachment that currently fits on the Roomba.
- You solution may introduce new things to the situation, such as items to facilitate cleaning. However, consider cost and effort with such suggestions. Ideas that cost too much or require owners to do too much will not be accepted.

### 3.2 CONSTRAINTS AND LIMITATIONS

- Your solution must not involve changes to the Roomba itself. You may change attachments, but not the main unit.
- The replacement bar costs about $13 which is too expensive for owners to replace the bar with every use. So, make sure any of your suggestions do not involve an additional cost of over $13.
- Cleaning a tangled bar requires 30-60 minutes of effort. Make sure your suggestions do not require more time on the part of the owners than this. In fact, you should consider suggestions requiring only 10 minutes or less of owner time.
- You should be aware of the complexity any of your suggestions involve. Don't expect owners to be able to reliably follow a list of instructions or effectively perform a sequence of tasks. Anything you require of the owner should be very simple.

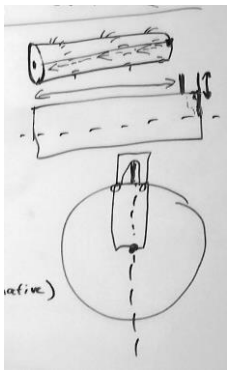
## 4. PROBLEM FORMULATION



## 5. IDEAS

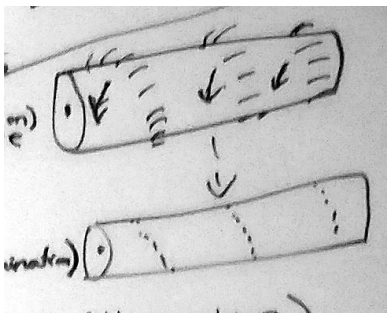
**Idea #1: Integrate Cutting Device**
This idea builds an apparatus into the beater bar to allow the user the convenience of slicing through any hair or debris that becomes wrapped up in the bristles and bar. The device stores into a recess on the side of the beater bar during operation and can then be activated and run along the length of the bar to slice through any obstruction for convenient removal as needed. The blade is recessed by a handle to prevent injury to the user.

| | |
|---|---|
| a. Travel through | (Alternative) |
| b. Nesting | (Resolution) |
| c. Preliminary Placement of an Object | (Resolution) |
| d. Specialization | (Alternative) |
| e. Integrate | (Alternative) |
| f. Use Disposable Object | (Elimination) |
| h. Add object with required properties | (Alternative) |



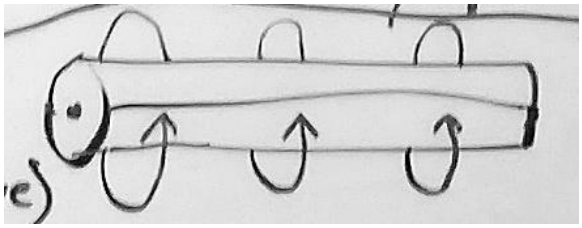
**Idea #2: Internalized Brush**
This design allows the bristles to be recessed into the beater bar itself. Should the bristles efficacy be impeded by hair or debris the user can simply relocate the bristles internally, allowing the user to remove the debris with minimal time and effort.

| | |
|---|---|
| a. Shelter inside another substance | (Elimination) |
| b. Nesting | (Resolution) |
| c. Shelter for a period of time | (Elimination) |
| d. Change to a Variable shape | (Alternative) |
| e. Separate Opposite Requirements in Space | (Resolution) |
| f. Exclude Sensitive Portion | (Elimination) |
| g. Add Object with required properties | (Alternative) |
| h. Use post processing time | (Resolution) |



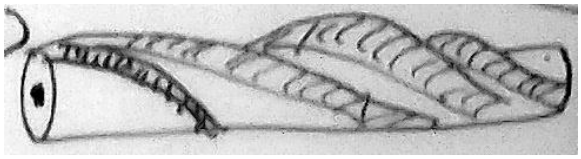
**Idea #3: Alternate Bar Surface (Removable sticky pad)**
In place of the traditional style of beater bar the cylinder has layers of adhesive material that can be peeled off, via a perforated seam, and disposed of as needed. After many cycles the user simply disposes of the empty cylinder sleeve, much like an empty roll of paper towels. This design is similar to a lint roller that utilizes layers similar to masking tape in material to remove debris/hair.

| | |
|---|---|
| a. Remove a substance or part | (Alternative) |
| b. Reduce weight of individual | (Alternative) |
| c. Use a disposable object | (Alternative/Elimination) |
| d. Make an object dismountable | (Alternative) |
| e. Preliminary Placement of an Object | (Resolution) |
| f. Add an object for a period of time | (Elimination) |
| g. Add a Carrier | (Elimination) |
| h. Use Inexpensive Objects | (Alternative) |
| i. Make a Road | (Resolution) |
| j. Use Subject Substance for a period of Time | (Elimination) |



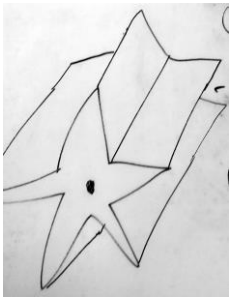
**Idea #4: Alternate Bar Surface (Hard Plastic)**
This idea replaces the bristled surface traditionally used on the beater bar for one that uses a hard-plastic wave design. This facilitates less surface resistance when the user goes to remove any hair or debris wrapped around the bar by simply sliding any entanglements off the end of the bar for disposal.

| | |
|---|---|
| a. Remove a substance or part | (Alternative) |
| b. Use unique shapes | (Alternative) |
| c. Strength individual parts | (Alternative) |
| d. Transform an Object's Shape | (Alternative) |
| e. Specialization | (Alternative) |
| f. Remove a required part from an object | (Resolution) |
| g. Exclude Auxiliary Functions | (Alternative) |



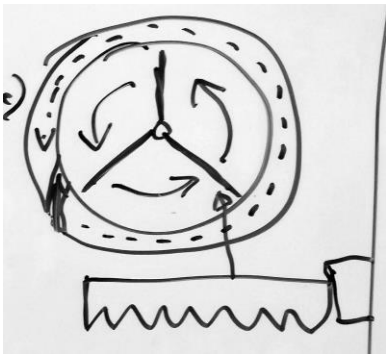
**Idea #5: Alternate Bar Surface (Star Rubber Bar)**
This idea suggests reshaping the existing design and material of the current beater bar. In place of the existing cylinder we reshape it to utilize paddles, made of hard rubber, in place of bristles. This allows any entangling debris to contact only the leading edge of each paddle. Ease of cleaning is achieved by reducing the surface area and creating adequate space for a cutting tool to be implemented. This results in a timely and more convenient manner of cleaning by the user.

| | |
|---|---|
| a. Use Flexible materials | (Alternative) |
| b. Add object with required properties | (Alternative) |
| c. Transform an objects shape | (Alternative) |



**Idea #6: Alternative Brush Design**
In place of the traditional design of a beater bar operating in a circular rotation parallel to the floor, we implement an attachment that has 3 hard-tooth combs that run parallel to the floor. The main attachment point is oriented perpendicular to the floor. This design is similar in operation to the way a push mower is designed.

| | |
|---|---|
| a. Remove a part or substance | (Elimination/Alternative) |
| b. Use unique shapes | (Alternative) |
| c. Partial/Excessive Action | (Alternative) |
| d. Duplicate critical elements | (Alternative) |
| e. Transform an object's shape | (Alternative) |
| f. Remove a required part from an object | (Resolution) |
| g. Fields in the system | (Resolution) |



**Idea #7: Integrated Self Cleaning Comb/Brush**
This idea incorporates a stationary comb on the underside of the frame that can be manually pressed, via a button, against the beater bar at operational speed to loosen and remove any debris wrapped around the beater bar/bristles.

| | |
|---|---|
| a. Preliminary action | (Resolution) |
| b. Preliminary placement of an object | (Resolution) |
| c. Integrate | (Alternative) |
| d. Apply contact Phenomena | (Elimination) |