Then and NOW

ROBOT VACUUM CLEANERS AND LAWN MOWERS

by Tom Carroll

It's Saturday morning and you've slept in. The bed is soft and cozy when you are awakened to the whir of a motor off in the distance. You look at your alarm clock and see the blue "8:00" shining back at you. Oh, yeah, it's time for my robot vacuum cleaner to begin its daily ritual. Then, suddenly, you hear a louder whirring noise outside your window as your robot lawn mower begins it weekly chore. "Dang," you mutter to yourself, "I've got to re-program those things to start later on Saturday; I need my sleep."

Ahh, the ubiquitous labor-saving tools of the modern age! These two appliances are the epitome of a robot experimenter's goal. Every homeowner would like a lawnmower that can decide when the grass needs to be mowed, have it exit from its storage area, and mow the lawn completely without a person's involvement. It must safely perform this task effectively in the midst of people, obstacles, children's toys, and pets. Today's homemaker wants the same thing in a vacuum cleaner for carpets and floors, but operating within the ever-changing environment of a home. Tall orders? Possibly — several decades ago.

Robot Vacuum Cleaners Design Dilemma

The first experimenter-built robot vacuum cleaners that I remember all used a "Dust Buster" type of battery-operated, hand-held vacuum cleaner mounted to a mobile robot base. These early machines were more of an experiment in functionality than actual usefulness. It did not take experimenters long to discover that a vacuum cleaner's cleaning power was not just a result of the vacuum level attained in "inches of water," but also the volume of air moved in cubic feet per minute at that lowered pressure. We've all seen the TV ad where the hand-held vacuum cleaner is attached to a large funnel and the spokesperson sucks a bowling ball onto the funnel and lifts it up. This in no way demonstrates the cleaning ability of a vacuum cleaner as we could easily do the same thing sucking with our mouth. If the funnel had an effective area of only 20 square inches touching the 16-pound ball, less than one pound per square inch (or two inches of mercury) of vacuum (out of 14.7 PSI) suction with your mouth could allow you to lift the ball. Vacuum cleaner design is a bit more complex than just raw suction.

Figure 1 shows an early home-built robot vacuum cleaner that was a work of art, though a bit tall to clean under most furniture. Frank Jenkins of the Robotics Society of California demonstrated his home vac for our group 15 years ago. At 23 inches high and 44 pounds, HomeR was a bit larger than today's machines, but contained over 80 sensors. It used an Ampro 386SX board computer with four megabytes of memory. It also had a Black and Decker hand vacuum system built in for the sweeping function and could find its way back to a charging dock. This beautiful machine may not have been able to snake its way under a low coffee table, but it was one of the most stunningly-built robots that I had ever seen.

Today's robot vacuum cleaner designers have been "backed into a corner" of sorts as they soon realized that greater cleaning ability required a larger motor. A larger motor required a larger battery. Longer operating time also required a larger battery. A smaller, practical size was certainly more desirable for a typical homemaker. All of these requirements were hard to meet in a mobile robot. What was the designer to do?

The first step was to reduce the motor's power requirements, thus reducing the battery size and, therefore, the overall machine's size and

Figure 1. This is Frank Jenkins' home-built robot.

weight. Now, with less effective suction and "cleaning power," the designer was left with slowing the robot vacuum's speed down to have the nozzle over a given area for a longer period of time, or, devising an overall better nozzle arrangement augmented with rotating brushes or similar devices.

The designers of the best-selling robot vacuum cleaners actually took many more design aspects into consideration such as height above the carpet or floor, number and location of "nozzles;" shape of the air flow channels; shape, speed, and location of brushes; number of passes over an area, and many more aspects. Then comes the navigation and steering of the robot cleaner. Do you just allow the machine to bump into walls, reverse, and then go off in another direction like a sheep randomly eating grass in a meadow? Eventually, the machine finally covers the entire carpet in a given room — or does it?

Does it keep bumping into the same chair and table legs, only to miss many areas of the carpet? Does the designer need to add optical or ultrasonic sensors to allow the robot to travel parallel to a wall without touching it? Does one need to add a higher-level processor to bit-map a room? Do you need to add sensors to detect what parts of the carpet the machine has covered by detecting carpet fibers brushed in a specific direction? How does the robot regain its original path once it detects an obstacle and goes around it? Detecting a full dirt bin, orientation, low batteries, dangerous overhangs, and getting permanently stuck were other designer problem areas. Today's robot vacuum manufacturers have solved these and many other design issues.

The iRobot Roomba

There is no doubt to all of us that the iRobot Roomba is the run-away best selling "home robot" ever, with over two million sold and counting, after its September 2002 debut. Back then, everyone was talking about Dean Kamen's Segway Transporter, as this other small New England company quietly designed and produced what many say is the first truly useful consumer robot. This amazing product that people have called a 'low-flying flying saucer,' a "Frisbee on steroids,' and even a 'bathroom scale that walks' is in millions of homes around the world.

The overall design and basic shape and size were not iRobot's biggest hurdle; their problem was how to make the robot vacuum affordable to be able to be sold through major retail chains. There were already some capable — but very expensive — robot vacuum cleaners on the market. In the beginning, they decided that they needed a simple eight-bit processor and a small number of parts that could be easily machined or molded, much like toy manufacturers who create amazing devices for child-sized budgets. Uniquely enough, iRobot did have experience with toy manufacturing — their disastrous My Real Baby, a robot doll that failed miserably in the toy market.

Roomba Design Constraints

iRobot wanted the Roomba to be effective on both carpeted and hard floors. Designer Joe Jones wasn't after a 'cool' factor; he wanted as machine that would do a job well. Jones — the lead designer for the Roomba — designed it with an undercarriage containing the dirt collection pan and the revolving brushes that rise or lower according to the floor type. You may remember him as the co-author of the great book *Mobile Robots — Inspiration to Implementation*.

When Roomba encounters friction-causing surfaces such as carpet, the torque derived from the friction on the brushes causes the assembly to rise a bit, thus lessening the load torque. When the load lessens — such as on a hard floor — the brush assembly lowers. This seemingly complex action is created by a simple string and friction clutch arrangement to keep the cost down. A single motor is used for the brush assembly and the lifting/lowering system. Roomba utilizes a spinning side brush to push dirt from edges into the path of the main cleaning head (see Figures 2 and 3).

The next generation of Roombas uses the C programming language and is compiled with commercially available software. A 16-bit Freescale Semiconductor MC9S12 processor using only 2K bytes of RAM executes the algorithms. Several years ago, they came out with the Roomba Pro and Pro Elite. The Roomba Pro Elite model included a remote control that allowed users to navigate the robot vacuum around a room, set cleaning options, and turn the Pro Elite on or off with the touch of a button. The Roomba Pro Elite also featured a "MAX" cleaning mode for multi-room cleaning or high-traffic areas. The software featured one or two virtual walls and a "cliff-avoidance" detector that prevented the robot from falling down stairs. "These newer generations are able to determine how large the room is and plot the most effective cleaning tactic based on the room's layout," says Colin Angle, iRobot's CEO.

The current cheapest model — Roomba Red — costs $150, though I've seen it on closeout sales for less than $75. The Roomba Sage model has a longer-lasting battery that charges faster, for an additional $50. Roomba Discovery goes for $250, has auto

Figure 2. The inside of the Roomba.

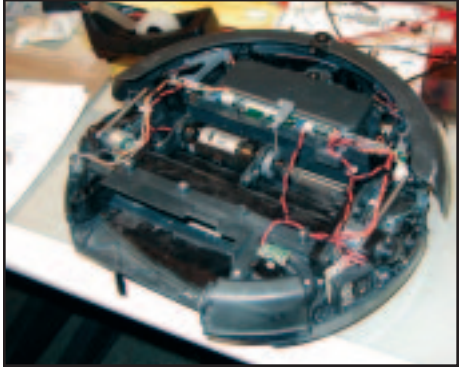

Figure 3. The bottom of the Roomba.

charging ability, and a larger trash bin, or, for $50 more, it can charge while hanging on the wall. Toss in an additional $30 ($330) for the Scheduler and you get the ultimate Roomba — one that you can schedule for the whole week's worth of cleaning.

Buyers must remember that the Roomba is not a deep-cleaning machine, just a daily 'touch up' device to keep your house presentable. You need to use a more powerful upright for deep cleaning and shag carpeting. Keep in mind also, that the Roomba is not pet-friendly. It won't attack your cat or dog, but it's a pretty sure thing that Fluffy will place it at the top of his enemy list.

The iRobot Scooba

iRobot's success with the Roomba made the step to the floor-scrubbing Scooba a natural direction to go. The Roomba did a good job of removing dust and dirt that was just lying on the surface of a hard floor, but most dirt adheres to floors and needs to be scrubbed off. This scrubbing action required a totally different type of cleaning system. As the company says: "Meet the Scooba Floor Washing Robot ... the world's first floor-washing robot for the home that preps, washes, scrubs, and dries your floor — all by itself.

Unlike mop and bucket methods that just spread dirty water around your floor, Scooba uses a fresh Clorox Scooba cleaning solution from start to finish. Figure 4 shows a diagram of how the solution is dispensed and sucked up after it's dirty. With the press of a button, the robot will leave your floors clean, dry, and ready to walk on. Scooba is simple to use, and safe on all sealed hardwood, tile, and linoleum flooring." What impressed me is the Scooba actually sucks up the dirty water from the first cycles and deposits it in another separate container that is emptied later. Figure 5 shows the interior of a Scooba.

Mowing the Lawn on Autopilot

The desire for a robotic lawnmower has been around about as long as the early vacuum cleaner ideas. Back in the mid '80s at a Robot Institute of America (RI/SME) conference, I took this photo of a robot lawnmower that was a bit more remote controlled than computer controlled (see Figure 6). Notice the toothed belt steering the four wheels to make it move in all directions like a crab, yet still be facing the same direction. It drew a substantial crowd of onlookers; pretty good from a bunch of industrial robot engineers.

Robot Lawn Mower Design Issues

Designers of robot mowers face some hurdles that aren't encountered by designers of robot vacuum cleaners. The number one issue is safety. Cutting grass is much more energy-intensive than sucking dirt off a carpet's surface, even with revolving brushes to assist in the task. Add to this many more square feet of grass in the typical yard than indoor carpeting and you have a need for a lot more energy on board a mower.

Build a machine with one to three spinning metal blades designed to cut things and you have a potential hazard to humans, animals, and property. Mowers have already been labeled hazardous machines by many government agencies and are required to have a "dead man's switch" that stops the blade (and engine) when the handle is released. This certainly does not stop the operator from running over a pile of small pebbles that can be slung in all directions. So, keeping in mind the "stupid factor," the manufacturers carefully evaluated the robot mower design process.

The RoboMower from Friendly Robotics

Lawn-tool company, Toro, markets a Robomower under the brand name iMow. Husqvarna — a division of a Swedish vacuum cleaner company, Electrolux — also sells a robotic lawn mower, the Auto Mower. But it is the Israeli company, Friendly Robotics, that leads the pack and has sold over 50,000 RoboMowers since 1998. Udi Peless and Shai Abramson — two Israelis with technical backgrounds — joined forces to produce the lawnmower back in 1995. Peless had already enjoyed quite a bit of success with a medical equipment start-up company and used his knowledge of navigation and control systems and Abramson's software background to start the company in a garage.

They were a bit overconfident in their ultimate success, but several million dollars and years later, they had a gasoline-powered "Lawn-Keeper" prototype in 1998. The first machine they had for sale used a 16-bit, 20 MHz Hitachi HS8 microcontroller to weigh inputs from various sensors and send controlling signals to the 150W drive wheel motors and a 750W cutter motor. They managed to sell 4,000 of these mowers by 2001. Later models changed the single cutter motor to three 150W motors, thus saving 300 watts. As any robot experimenter can

Figure 4. Scooba cleaning illustration.

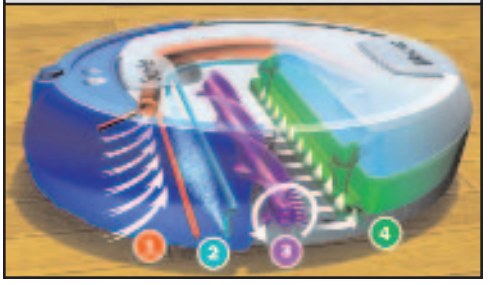

Figure 5. The inside of the Scooba.

Figure 6. An early robot lawnmower.

Figure 7. The RL1000 RoboMower and its dock.

Figure 8. Mower blades.

Figure 9. The RoboMower RL850.

attest to, it was the development of the software that offered them the greatest challenge, not the hardware.

Friendly Robotics credits the Roomba for boosting interest in its robotic lawn mowers. "Roomba has given us a lot of forward momentum," said Mike Dunigan, vice president of sales at Friendly Robotics, USA. He says that dogs, cats, and kids are safe around the Robomower. "Dogs bark at it about an hour before they finally give up on it," he said. "Cats hide." A slight pressure on any side of the Robomower will cause it to turn around, and the mower's blades shut off in less than a second if the machine is lifted off the ground.

The RL1000 RoboMower is the top-of-the-line and retails for about $1,800. It is designed to mow a lawn all by itself (Figure 7). The mower begins its chores automatically and then navigates back to its docking station when it needs recharging. "Designed for domestic lawns and gardens, it can handle any mowing task that a traditional gas or electric mower can handle, irrespective of the shape and slopes of the garden, obstacles, and type of lawn," says Dunigan. It features a three blade, 53 cm (21 inch) powerful cutting system (see Figure 8). It is kept within a specific lawn area by using buried and electromagnetic field-emitting "Perimeter Switch" wires as an invisible fence, much like dog fences. When the RoboMower returns to the docking station, the perimeter switch turns itself off.

"RoboMower is a dedicated mulching mower that mulches better than a traditional mower thanks to its Triple-Chamber-Mulching system and the 5800-RPM blade speed — double that of a typical gas mower. Grass is cut into very small clippings that are buried in the roots of the lawn, where they decompose and act like a natural fertilizer. This results in a healthier and better looking lawn, and eliminates the need to collect and remove the clippings," according to Dunigan. Figure 9 shows the less-expensive RoboMower RL850 — a mower system that does not have the automatic task time programming, auto-return to a docking station, and the intelligent perimeter switch system.

You can obtain information for the robot vacuums and lawn mowers at either **www.irobot.com** or **www.friendlyrobotics.com**. SV

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