US008528157B2

(12) **United States Patent** (10) **Patent No.:** **US 8,528,157 B2**
Schnittman et al. (45) **Date of Patent:** **Sep. 10, 2013**

(54) **COVERAGE ROBOTS AND ASSOCIATED CLEANING BINS**

(75) Inventors: **Mark Schnittman**, Cambridge, MA (US); **Daniel N. Ozick**, Newton, MA (US); **Gregg W. Landry**, Gloucester, MA (US)

(73) Assignee: **iRobot Corporation**, Bedford, MA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 1003 days.

(21) Appl. No.: **11/751,267**

(22) Filed: **May 21, 2007**

(65) **Prior Publication Data**

US 2008/0047092 A1 Feb. 28, 2008

Related U.S. Application Data

(60) Provisional application No. 60/747,791, filed on May 19, 2006, provisional application No. 60/803,504, filed on May 30, 2006, provisional application No. 60/807,442, filed on Jul. 14, 2006.

(51) **Int. Cl.**
A47L 7/00 (2006.01)
A47L 11/24 (2006.01)
A47L 11/40 (2006.01)

(52) **U.S. Cl.**
USPC **15/319**; 15/3; 15/52.2; 15/340.1; 15/339; 318/580

(58) **Field of Classification Search**
USPC 15/319, 3, 52.2, 339, 340.1; 318/580
IPC A47L 7/00, 11/24, 11/40
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

1,755,054	A	4/1930	Darst
1,780,221	A	11/1930	Buchmann
1,970,302	A	8/1934	Gerhardt

(Continued)

FOREIGN PATENT DOCUMENTS

AU	2003275566 A1	6/2004
DE	2128842 C3	12/1980

(Continued)

OTHER PUBLICATIONS

Prassler et al., "A Short History of Cleaning Robots", Autonomous Robots 9, 211-226, 2000.

(Continued)

Primary Examiner — Monica Carter
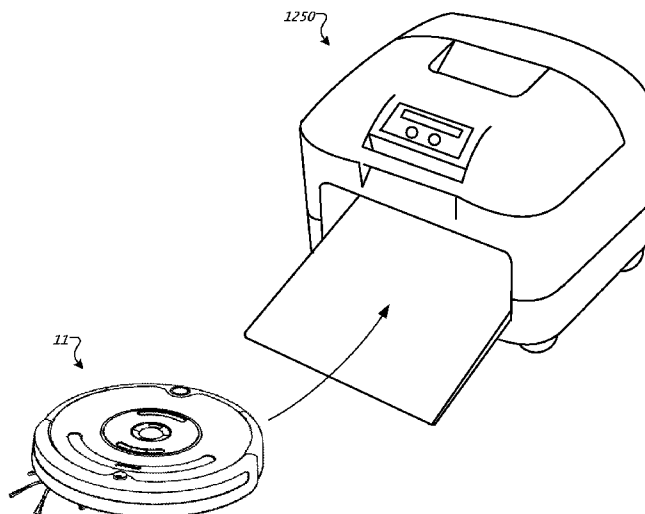*Assistant Examiner* — Stephanie Berry
(74) *Attorney, Agent, or Firm* — Fish & Richardson P.C.

(57) **ABSTRACT**

An autonomous coverage robot includes a chassis, a drive system configured to maneuver the robot, and a cleaning assembly. The cleaning assembly includes a cleaning assembly housing and at least one driven sweeper brush. The robot includes a controller and a removable sweeper bin configured to receive debris agitated by the driven sweeper brush. The sweeper bin includes an emitter disposed on an interior surface of the bin and a receiver disposed remotely from the emitter on the interior surface of the bin and configured to receive an emitter signal. The emitter and the receiver are disposed such that a threshold level of accumulation of debris in the sweeper bin blocks the receiver from receiving emitter emissions. The robot includes a bin controller disposed in the sweeper bin and monitoring a detector signal and initiating a bin full routine upon determining a bin debris accumulation level requiring service.

17 Claims, 21 Drawing Sheets

(56) **References Cited**

U.S. PATENT DOCUMENTS

2,136,324 A	11/1938	John
2,302,111 A	11/1942	Dow et al.
2,353,621 A	7/1944	Sav et al.
2,770,825 A	11/1956	Pullen
3,119,369 A	1/1964	Harland et al.
3,166,138 A	1/1965	Dunn
3,333,564 A	8/1967	Waters
3,375,375 A	3/1968	Robert et al.
3,381,652 A	5/1968	Schaefer et al.
3,457,575 A	7/1969	Bienek
3,550,714 A	12/1970	Bellinger
3,569,727 A	3/1971	Aggarwal et al.
3,674,316 A	7/1972	De Brey
3,678,882 A	7/1972	Kinsella
3,744,586 A	7/1973	Leinauer
3,756,667 A	9/1973	Bombardier et al.
3,809,004 A	5/1974	Leonheart
3,816,004 A	6/1974	Bignardi
3,845,831 A	11/1974	James
RE28,268 E	12/1974	Autrand
3,853,086 A	12/1974	Asplund
3,863,285 A	2/1975	Hukuba
3,888,181 A	6/1975	Kups
3,937,174 A	2/1976	Haaga
3,952,361 A	4/1976	Wilkins
3,989,311 A	11/1976	De Brey
3,989,931 A	11/1976	Phillips
4,004,313 A	1/1977	Capra
4,012,681 A	3/1977	Finger et al.
4,070,170 A	1/1978	Leinfelt
4,099,284 A	7/1978	Shinozaki et al.
4,119,900 A	10/1978	Kremnitz
4,175,589 A	11/1979	Nakamura et al.
4,175,892 A	11/1979	De Brey
4,196,727 A	4/1980	Verkaart et al.
4,198,727 A	4/1980	Farmer
4,199,838 A	4/1980	Simonsson
4,209,254 A	6/1980	Reymond et al.
D258,901 S	4/1981	Keyworth
4,297,578 A	10/1981	Carter
4,306,329 A	12/1981	Yokoi
4,309,758 A	1/1982	Halsall et al.
4,328,545 A	5/1982	Halsall et al.
4,367,403 A	1/1983	Miller
4,369,543 A	1/1983	Chen et al.
4,401,909 A	8/1983	Gorsek
4,416,033 A	11/1983	Specht
4,445,245 A	5/1984	Lu
4,465,370 A	8/1984	Yuasa et al.
4,477,998 A	10/1984	You
4,481,692 A	11/1984	Kurz
4,482,960 A	11/1984	Pryor
4,492,058 A	1/1985	Goldfarb et al.
4,513,469 A	4/1985	Godfrey et al.
D278,732 S	5/1985	Ohkado
4,518,437 A	5/1985	Sommer
4,534,637 A	8/1985	Suzuki et al.
4,556,313 A	12/1985	Miller et al.
4,575,211 A	3/1986	Matsumura et al.
4,580,311 A	4/1986	Kurz
4,601,082 A	7/1986	Kurz
4,618,213 A	10/1986	Chen
4,620,285 A	10/1986	Perdue
4,624,026 A	11/1986	Olson et al.
4,626,995 A	12/1986	Lofgren et al.
4,628,454 A	12/1986	Ito
4,638,445 A	1/1987	Mattaboni
4,644,156 A	2/1987	Takahashi et al.
4,649,504 A	3/1987	Krouglicof et al.
4,652,917 A	3/1987	Miller
4,654,492 A	3/1987	Koerner et al.
4,654,924 A	4/1987	Getz et al.
4,660,969 A	4/1987	Sorimachi et al.
4,662,854 A	5/1987	Fang
4,674,048 A	6/1987	Okumura
4,679,152 A	7/1987	Perdue
4,680,827 A	7/1987	Hummel
4,696,074 A	9/1987	Cavalli et al.
D292,223 S	10/1987	Trumbull
4,700,301 A	10/1987	Dyke
4,700,427 A	10/1987	Knepper
4,703,820 A	11/1987	Reinaud
4,710,020 A	12/1987	Maddox et al.
4,716,621 A	1/1988	Zoni
4,728,801 A	3/1988	O'Connor
4,733,343 A	3/1988	Yoneda et al.
4,733,430 A	3/1988	Westergren
4,733,431 A	3/1988	Martin
4,735,136 A	4/1988	Lee et al.
4,735,138 A	4/1988	Gawler et al.
4,748,336 A	5/1988	Fujie et al.
4,748,833 A	6/1988	Nagasawa
4,756,049 A	7/1988	Uehara
4,767,213 A	8/1988	Hummel
4,769,700 A	9/1988	Pryor
4,777,416 A	10/1988	George, II et al.
D298,766 S	11/1988	Tanno et al.
4,782,550 A	11/1988	Jacobs
4,796,198 A	1/1989	Boultinghouse et al.
4,806,751 A	2/1989	Abe et al.
4,811,228 A	3/1989	Hyyppa
4,813,906 A	3/1989	Matsuyama et al.
4,815,157 A	3/1989	Tsuchiya
4,817,000 A	3/1989	Eberhardt
4,818,875 A	4/1989	Weiner
4,829,442 A	5/1989	Kadonoff et al.
4,829,626 A	5/1989	Harkonen et al.
4,832,098 A	5/1989	Palinkas et al.
4,851,661 A	7/1989	Everett, Jr.
4,854,000 A	8/1989	Takimoto
4,854,006 A	8/1989	Nishimura et al.
4,855,915 A	8/1989	Dallaire
4,857,912 A	8/1989	Everett et al.
4,858,132 A	8/1989	Holmquist
4,867,570 A	9/1989	Sorimachi et al.
4,880,474 A	11/1989	Koharagi et al.
4,887,415 A	12/1989	Martin
4,891,762 A	1/1990	Chotiros
4,893,025 A	1/1990	Lee
4,901,394 A	2/1990	Nakamura et al.
4,905,151 A	2/1990	Weiman et al.
4,912,643 A	3/1990	Beirne
4,918,441 A	4/1990	Bohman
4,919,224 A	4/1990	Shyu et al.
4,919,489 A	4/1990	Kopsco
4,920,060 A	4/1990	Parrent et al.
4,920,605 A	5/1990	Takashima
4,933,864 A	6/1990	Evans et al.
4,937,912 A	7/1990	Kurz
4,953,253 A	9/1990	Fukuda et al.
4,954,962 A	9/1990	Evans et al.
4,955,714 A	9/1990	Stotler et al.
4,956,891 A	9/1990	Wulff
4,961,303 A	10/1990	McCarty et al.
4,961,304 A	10/1990	Ovsborn et al.
4,962,453 A	10/1990	Pong et al.
4,971,591 A	11/1990	Raviv et al.
4,973,912 A	11/1990	Kaminski et al.
4,974,283 A	12/1990	Holsten et al.
4,977,618 A	12/1990	Allen
4,977,639 A	12/1990	Takahashi et al.
4,986,663 A	1/1991	Cecchi et al.
5,001,635 A	3/1991	Yasutomi et al.
5,002,145 A	3/1991	Waqkaumi et al.
5,012,886 A	5/1991	Jonas et al.
5,018,240 A	5/1991	Holman
5,020,186 A	6/1991	Lessig et al.
5,022,812 A	6/1991	Coughlan et al.
5,023,788 A	6/1991	Kitazume et al.
5,024,529 A	6/1991	Svetkoff et al.
D318,500 S	7/1991	Malewicki et al.
5,032,775 A	7/1991	Mizuno et al.
5,033,151 A	7/1991	Kraft et al.
5,033,291 A	7/1991	Podoloff et al.

5,040,116	A		8/1991	Evans et al.	5,446,445	A	8/1995	Bloomfield et al.
5,045,769	A		9/1991	Everett	5,451,135	A	9/1995	Schempf et al.
5,049,802	A		9/1991	Mintus et al.	5,454,129	A	10/1995	Kell
5,051,906	A		9/1991	Evans et al.	5,455,982	A	10/1995	Armstrong et al.
5,062,819	A		11/1991	Mallory	5,465,525	A	11/1995	Mifune et al.
5,070,567	A		12/1991	Holland	5,465,619	A	11/1995	Sotack et al.
5,084,934	A		2/1992	Lessig et al.	5,467,273	A	11/1995	Faibish et al.
5,086,535	A		2/1992	Grossmeyer et al.	5,471,560	A	11/1995	Allard et al.
5,090,321	A		2/1992	Abouav	5,491,670	A	2/1996	Weber
5,093,955	A		3/1992	Blehert et al.	5,497,529	A	3/1996	Boesi
5,094,311	A		3/1992	Akeel	5,498,948	A	3/1996	Bruni et al.
5,105,502	A		4/1992	Takashima	5,502,638	A	3/1996	Takenaka
5,105,550	A		4/1992	Shenoha	5,505,072	A	4/1996	Oreper
5,109,566	A		5/1992	Kobayashi et al.	5,507,067	A	4/1996	Hoekstra et al.
5,115,538	A		5/1992	Cochran et al.	5,510,893	A	4/1996	Suzuki
5,127,128	A		7/1992	Lee	5,511,147	A	4/1996	Abdel-Malek
5,136,675	A		8/1992	Hodson	5,515,572	A	5/1996	Hoekstra et al.
5,136,750	A		8/1992	Takashima et al.	5,534,762	A	7/1996	Kim
5,142,985	A		9/1992	Stearns et al.	5,537,017	A	7/1996	Feiten et al.
5,144,471	A		9/1992	Takanashi et al.	5,537,711	A	7/1996	Tseng
5,144,714	A		9/1992	Mori et al.	5,539,953	A	7/1996	Kurz
5,144,715	A		9/1992	Matsuyo et al.	5,542,146	A	8/1996	Hoekstra et al.
5,152,028	A		10/1992	Hirano	5,542,148	A	8/1996	Young
5,152,202	A		10/1992	Strauss	5,546,631	A	8/1996	Chambon
5,155,684	A		10/1992	Burke et al.	5,548,511	A	8/1996	Bancroft
5,163,202	A	*	11/1992	Kawakami et al. 15/319	5,551,525	A	9/1996	Pack et al.
5,163,320	A		11/1992	Goshima et al.	5,553,349	A	9/1996	Kilstrom et al.
5,164,579	A		11/1992	Pryor et al.	5,555,587	A	9/1996	Guha
5,165,064	A		11/1992	Mattaboni	5,560,077	A	10/1996	Crotchett
5,170,352	A		12/1992	McTamaney et al.	5,568,589	A	10/1996	Hwang
5,173,881	A		12/1992	Sindle	D375,592	S	11/1996	Ljunggren
5,182,833	A		2/1993	Yamaguchi et al.	5,608,306	A	3/1997	Rybeck et al.
5,202,742	A		4/1993	Frank et al.	5,608,894	A	3/1997	Kawakami et al.
5,204,814	A		4/1993	Noonan et al.	5,608,944	A	3/1997	Gordon
5,206,500	A		4/1993	Decker et al.	5,610,488	A	3/1997	Miyazawa
5,208,521	A		5/1993	Aoyama	5,611,106	A	3/1997	Wulff
5,216,777	A		6/1993	Moro et al.	5,611,108	A	3/1997	Knowlton et al.
5,227,985	A		7/1993	DeMenthon	5,613,261	A	3/1997	Kawakami et al.
5,233,682	A		8/1993	Abe et al.	5,613,269	A	3/1997	Miwa
5,239,720	A		8/1993	Wood et al.	5,621,291	A	4/1997	Lee
5,251,358	A		10/1993	Moro et al.	5,622,236	A	4/1997	Azumi et al.
5,261,139	A		11/1993	Lewis	5,634,237	A	6/1997	Paranjpe
5,276,618	A		1/1994	Everett	5,634,239	A	6/1997	Tuvin et al.
5,276,939	A		1/1994	Uenishi	5,636,402	A	6/1997	Kubo et al.
5,277,064	A		1/1994	Knigga et al.	5,642,299	A	6/1997	Hardin et al.
5,279,672	A		1/1994	Belker, Jr. et al.	5,646,494	A	7/1997	Han
5,284,452	A		2/1994	Corona	5,647,554	A	7/1997	Ikegami et al.
5,284,522	A		2/1994	Kobayashi et al.	5,650,702	A	7/1997	Azumi
5,293,955	A		3/1994	Lee	5,652,489	A	7/1997	Kawakami
D345,707	S		4/1994	Alister	5,682,313	A	10/1997	Edlund et al.
5,303,448	A		4/1994	Hennessey et al.	5,682,839	A	11/1997	Grimsley et al.
5,307,273	A		4/1994	Oh et al.	5,696,675	A	12/1997	Nakamura et al.
5,309,592	A		5/1994	Hiratsuka	5,698,861	A	12/1997	Oh
5,310,379	A		5/1994	Hippely et al.	5,709,007	A	1/1998	Chiang
5,315,227	A		5/1994	Pierson et al.	5,710,506	A	1/1998	Broell et al.
5,319,827	A		6/1994	Yang	5,714,119	A	2/1998	Kawagoe et al.
5,319,828	A		6/1994	Waldhauser et al.	5,717,169	A	2/1998	Liang et al.
5,321,614	A		6/1994	Ashworth	5,717,484	A	2/1998	Hamaguchi et al.
5,323,483	A		6/1994	Baeg	5,720,077	A	2/1998	Nakamura et al.
5,324,948	A		6/1994	Dudar et al.	5,732,401	A	3/1998	Conway
5,341,186	A		8/1994	Kato	5,735,959	A	4/1998	Kubo et al.
5,341,540	A		8/1994	Soupert et al.	5,745,235	A	4/1998	Vercammen et al.
5,341,549	A		8/1994	Wirtz et al.	5,752,871	A	5/1998	Tsuzuki
5,345,649	A		9/1994	Whitlow	5,756,904	A	5/1998	Oreper et al.
5,353,224	A		10/1994	Lee et al.	5,761,762	A	6/1998	Kubo et al.
5,363,305	A		11/1994	Cox et al.	5,764,888	A	6/1998	Bolan et al.
5,363,935	A		11/1994	Schempf et al.	5,767,437	A	6/1998	Rogers
5,369,347	A		11/1994	Yoo	5,767,960	A	6/1998	Orman
5,369,838	A		12/1994	Wood et al.	5,777,596	A	7/1998	Herbert
5,386,862	A		2/1995	Glover et al.	5,778,486	A	7/1998	Kim
5,399,951	A		3/1995	Lavallee et al.	5,781,697	A	7/1998	Jeong
5,400,244	A		3/1995	Watanabe et al.	5,781,960	A	7/1998	Kilstrom et al.
5,404,612	A		4/1995	Ishikawa	5,786,602	A	7/1998	Pryor et al.
5,410,479	A		4/1995	Coker	5,787,545	A	8/1998	Colens
5,435,405	A		7/1995	Schempf et al.	5,793,900	A	8/1998	Nourbakhsh et al.
5,440,216	A		8/1995	Kim	5,794,297	A	8/1998	Muta
5,442,358	A		8/1995	Keeler et al.	5,812,267	A	9/1998	Everett et al.
5,444,965	A		8/1995	Colens	5,814,808	A	9/1998	Takada et al.
5,446,356	A		8/1995	Kim	5,815,880	A	10/1998	Nakanishi

5,815,884	A	10/1998	Imamura et al.	6,101,670	A	8/2000	Song
5,819,008	A	10/1998	Asama et al.	6,101,671	A	8/2000	Wright et al.
5,819,360	A	10/1998	Fujii	6,108,031	A	8/2000	King et al.
5,819,936	A	10/1998	Saveliev et al.	6,108,067	A	8/2000	Okamoto
5,820,821	A	10/1998	Kawagoe et al.	6,108,076	A	8/2000	Hanseder
5,821,730	A	10/1998	Drapkin	6,108,269	A	8/2000	Kabel
5,825,981	A	10/1998	Matsuda	6,108,597	A	8/2000	Kirchner et al.
5,828,770	A	10/1998	Leis et al.	6,112,143	A	8/2000	Allen et al.
5,831,597	A	11/1998	West et al.	6,112,996	A	9/2000	Matsuo
5,839,156	A	11/1998	Park et al.	6,119,057	A	9/2000	Kawagoe
5,839,532	A	11/1998	Yoshiji et al.	6,122,798	A	9/2000	Kobayashi et al.
5,841,259	A	11/1998	Kim et al.	6,124,694	A	9/2000	Bancroft et al.
5,867,800	A	2/1999	Leif	6,125,498	A	10/2000	Roberts et al.
5,869,910	A	2/1999	Colens	6,131,237	A	10/2000	Kasper et al.
5,896,611	A	4/1999	Haaga	6,138,063	A	10/2000	Himeda
5,903,124	A	5/1999	Kawakami	6,142,252	A	11/2000	Kinto et al.
5,905,209	A	5/1999	Oreper	6,146,278	A	11/2000	Kobayashi
5,907,886	A	6/1999	Buscher	6,154,279	A	11/2000	Thayer
5,910,700	A	6/1999	Crotzer	6,154,694	A	11/2000	Aoki et al.
5,911,260	A	6/1999	Suzuki	6,160,479	A	12/2000	Ahlen et al.
5,916,008	A	6/1999	Wong	6,167,332	A	12/2000	Kurtzberg et al.
5,924,167	A	7/1999	Wright et al.	6,167,587	B1	1/2001	Kasper et al.
5,926,909	A	7/1999	McGee	6,192,548	B1	2/2001	Huffman
5,933,102	A	8/1999	Miller et al.	6,216,307	B1	4/2001	Kaleta et al.
5,933,913	A	8/1999	Wright et al.	6,220,865	B1	4/2001	Macri et al.
5,935,179	A	8/1999	Kleiner et al.	6,226,830	B1	5/2001	Hendriks et al.
5,940,346	A	8/1999	Sadowsky et al.	6,230,362	B1	5/2001	Kasper et al.
5,940,927	A	8/1999	Haegermarck et al.	6,237,741	B1	5/2001	Guidetti
5,940,930	A	8/1999	Oh et al.	6,240,342	B1	5/2001	Fiegert et al.
5,942,869	A	8/1999	Katou et al.	6,243,913	B1	6/2001	Frank et al.
5,943,730	A	8/1999	Boomgaarden	6,255,793	B1	7/2001	Peless et al.
5,943,733	A	8/1999	Tagliaferri	6,259,979	B1	7/2001	Holmquist
5,947,225	A	9/1999	Kawakami et al.	6,261,379	B1	7/2001	Conrad et al.
5,950,408	A	9/1999	Schaedler	6,263,539	B1	7/2001	Baig
5,959,423	A	9/1999	Nakanishi et al.	6,263,989	B1	7/2001	Won
5,968,281	A	10/1999	Wright et al.	6,272,936	B1	8/2001	Oreper et al.
5,974,348	A	10/1999	Rocks	6,276,478	B1	8/2001	Hopkins et al.
5,974,365	A	10/1999	Mitchell	6,278,918	B1	8/2001	Dickson et al.
5,983,448	A	11/1999	Wright et al.	6,282,526	B1	8/2001	Ganesh
5,984,880	A	11/1999	Lander et al.	6,283,034	B1	9/2001	Miles
5,987,383	A	11/1999	Keller et al.	6,285,778	B1	9/2001	Nakajima et al.
5,989,700	A	11/1999	Krivopal	6,285,930	B1	9/2001	Dickson et al.
5,991,951	A	11/1999	Kubo et al.	6,300,737	B1	10/2001	Bergvall et al.
5,995,883	A	11/1999	Nishikado	6,321,337	B1	11/2001	Reshef et al.
5,995,884	A	11/1999	Allen et al.	6,321,515	B1	11/2001	Colens
5,996,167	A	12/1999	Close	6,323,570	B1	11/2001	Nishimura et al.
5,998,953	A	12/1999	Nakamura et al.	6,324,714	B1	12/2001	Walz et al.
5,998,971	A	12/1999	Corbridge	6,327,741	B1	12/2001	Reed
6,000,088	A	12/1999	Wright et al.	6,332,400	B1	12/2001	Meyer
6,009,358	A	12/1999	Angott et al.	6,339,735	B1	1/2002	Peless et al.
6,021,545	A	2/2000	Delgado et al.	6,362,875	B1	3/2002	Burkley
6,023,813	A	2/2000	Thatcher et al.	6,370,453	B2	4/2002	Sommer
6,023,814	A	2/2000	Imamura	6,374,155	B1	4/2002	Wallach et al.
6,025,687	A	2/2000	Himeda et al.	6,374,157	B1	4/2002	Takamura
6,026,539	A	2/2000	Mouw et al.	6,381,802	B2	5/2002	Park
6,030,464	A	2/2000	Azevedo	6,385,515	B1	5/2002	Dickson et al.
6,030,465	A	2/2000	Marcussen et al.	6,388,013	B1	5/2002	Saraf et al.
6,032,542	A	3/2000	Warnick et al.	6,389,329	B1	5/2002	Colens
6,036,572	A	3/2000	Sze	6,400,048	B1	6/2002	Nishimura et al.
6,038,501	A	3/2000	Kawakami	6,401,294	B2	6/2002	Kasper
6,040,669	A	3/2000	Hog	6,408,226	B1	6/2002	Byrne et al.
6,041,471	A	3/2000	Charkey et al.	6,412,141	B2	7/2002	Kasper et al.
6,041,472	A	3/2000	Kasen et al.	6,415,203	B1	7/2002	Inoue et al.
6,046,800	A	4/2000	Ohtomo et al.	6,421,870	B1	7/2002	Basham et al.
6,049,620	A	4/2000	Dickinson et al.	6,427,285	B1	8/2002	Legatt et al.
6,052,821	A	4/2000	Chouly et al.	6,430,471	B1	8/2002	Kintou et al.
6,055,042	A	4/2000	Sarangapani	6,431,296	B1	8/2002	Won
6,055,702	A	5/2000	Imamura et al.	6,437,227	B1	8/2002	Theimer
6,061,868	A	5/2000	Moritsch et al.	6,437,465	B1	8/2002	Nishimura et al.
6,065,182	A	5/2000	Wright et al.	6,438,456	B1	8/2002	Feddema et al.
6,073,432	A	6/2000	Schaedler	6,438,793	B1	8/2002	Miner et al.
6,076,025	A	6/2000	Ueno et al.	6,442,476	B1	8/2002	Poropat
6,076,026	A	6/2000	Jambhekar et al.	6,443,509	B1	9/2002	Levin et al.
6,076,226	A	6/2000	Reed	6,444,003	B1	9/2002	Sutcliffe
6,076,227	A	6/2000	Schallig et al.	6,446,302	B1	9/2002	Kasper et al.
6,081,257	A	6/2000	Zeller	6,454,036	B1	9/2002	Airey et al.
6,088,020	A	7/2000	Mor	D464,091	S	10/2002	Christianson
6,094,775	A	8/2000	Behmer	6,457,206	B1	10/2002	Judson
6,099,091	A	8/2000	Campbell	6,459,955	B1	10/2002	Bartsch et al.

6,463,368 B1	10/2002	Feiten et al.	
6,465,982 B1	10/2002	Bergvall et al.	
6,473,167 B1	10/2002	Odell	
6,480,762 B1	11/2002	Uchikubo et al.	
6,481,515 B1	11/2002	Kirkpatrick et al.	
6,490,539 B1	12/2002	Dickson et al.	
6,491,127 B1	12/2002	Holmberg et al.	
6,493,612 B1	12/2002	Bisset et al.	
6,493,613 B2	12/2002	Peless et al.	
6,496,754 B2	12/2002	Song et al.	
6,496,755 B2	12/2002	Wallach et al.	
6,502,657 B2	1/2003	Kerrebrock et al.	
6,504,610 B1	1/2003	Bauer et al.	
6,507,773 B2	1/2003	Parker et al.	
6,525,509 B1	2/2003	Petersson et al.	
D471,243 S	3/2003	Cioffi et al.	
6,532,404 B2	3/2003	Colens	
6,535,793 B2	3/2003	Allard	
6,540,607 B2	4/2003	Mokris et al.	
6,548,982 B1	4/2003	Papanikolopoulos et al.	
6,553,612 B1	4/2003	Dyson et al.	
6,556,722 B1	4/2003	Russell et al.	
6,556,892 B2	4/2003	Kuroki et al.	
6,557,104 B2	4/2003	Vu et al.	
D474,312 S	5/2003	Stephens et al.	
6,563,130 B2	5/2003	Dworkowski et al.	
6,571,415 B2	6/2003	Gerber et al.	
6,571,422 B1	6/2003	Gordon et al.	
6,572,711 B2	6/2003	Sclafani et al.	
6,574,536 B1	6/2003	Kawagoe et al.	
6,580,246 B2	6/2003	Jacobs	
6,584,376 B1	6/2003	Van Kommer	
6,586,908 B2	7/2003	Petersson et al.	
6,587,573 B1	7/2003	Stam et al.	
6,590,222 B1	7/2003	Bisset et al.	
6,594,551 B2	7/2003	McKinney et al.	
6,594,844 B2	7/2003	Jones	
D478,884 S	8/2003	Slipy et al.	
6,601,265 B1	8/2003	Burlington	
6,604,021 B2	8/2003	Imai et al.	
6,604,022 B2	8/2003	Parker et al.	
6,605,156 B1	8/2003	Clark et al.	
6,611,120 B2	8/2003	Song et al.	
6,611,734 B2	8/2003	Parker et al.	
6,611,738 B2	8/2003	Ruffner	
6,615,108 B1	9/2003	Peless et al.	
6,615,885 B1	9/2003	Ohm	
6,622,465 B2	9/2003	Jerome et al.	
6,624,744 B1	9/2003	Wilson et al.	
6,625,843 B2	9/2003	Kim et al.	
6,629,028 B2	9/2003	Paromtchik et al.	
6,639,659 B2	10/2003	Granger	
6,658,325 B2	12/2003	Zweig	
6,658,354 B2	12/2003	Lin	
6,658,692 B2	12/2003	Lenkiewicz et al.	
6,658,693 B1	12/2003	Reed, Jr.	
6,661,239 B1	12/2003	Ozick	
6,662,889 B2	12/2003	De Fazio et al.	
6,668,951 B2	12/2003	Won	
6,670,817 B2	12/2003	Fournier et al.	
6,671,592 B1	12/2003	Bisset et al.	
6,687,571 B1	2/2004	Byrne et al.	
6,690,134 B1 *	2/2004	Jones et al. 318/567	
6,690,993 B2	2/2004	Foulke et al.	
6,697,147 B2	2/2004	Ko et al.	
6,711,280 B2	3/2004	Stafsudd et al.	
6,732,826 B2 *	5/2004	Song et al. 180/169	
6,737,591 B1	5/2004	Lapstun et al.	
6,741,054 B2	5/2004	Koselka et al.	
6,741,364 B2	5/2004	Lange et al.	
6,748,297 B2	6/2004	Song et al.	
6,756,703 B2	6/2004	Chang	
6,760,647 B2	7/2004	Nourbakhsh et al.	
6,764,373 B1	7/2004	Osawa et al.	
6,769,004 B2	7/2004	Barrett	
6,774,596 B1	8/2004	Bisset	
6,779,380 B1	8/2004	Nieuwkamp	
6,781,338 B2	8/2004	Jones et al.	
6,809,490 B2	10/2004	Jones et al.	
6,810,305 B2	10/2004	Kirkpatrick	
6,830,120 B1	12/2004	Yashima et al.	
6,832,407 B2	12/2004	Salem et al.	
6,836,701 B2	12/2004	McKee	
6,841,963 B2	1/2005	Song et al.	
6,845,297 B2	1/2005	Allard	
6,856,811 B2	2/2005	Burdue et al.	
6,859,010 B2	2/2005	Jeon et al.	
6,859,682 B2	2/2005	Naka et al.	
6,860,206 B1	3/2005	Rudakevych et al.	
6,865,447 B2	3/2005	Lau et al.	
6,870,792 B2	3/2005	Chiappetta	
6,871,115 B2	3/2005	Huang et al.	
6,883,201 B2	4/2005	Jones et al.	
6,886,651 B1	5/2005	Slocum et al.	
6,888,333 B2	5/2005	Laby	
6,901,624 B2	6/2005	Mori et al.	
6,906,702 B1	6/2005	Tanaka et al.	
6,914,403 B2	7/2005	Tsurumi	
6,917,854 B2	7/2005	Bayer	
6,925,357 B2	8/2005	Wang	
6,925,679 B2	8/2005	Wallach et al.	
6,929,548 B2	8/2005	Wang	
D510,066 S	9/2005	Hickey et al.	
6,938,298 B2	9/2005	Aasen	
6,940,291 B1	9/2005	Ozick	
6,941,199 B1	9/2005	Bottomley et al.	
6,956,348 B2	10/2005	Landry et al.	
6,957,712 B2	10/2005	Song et al.	
6,960,986 B2	11/2005	Asama et al.	
6,965,209 B2	11/2005	Jones et al.	
6,965,211 B2	11/2005	Tsurumi	
6,968,592 B2 *	11/2005	Takeuchi et al. 15/319	
6,971,140 B2	12/2005	Kim	
6,975,246 B1	12/2005	Trudeau	
6,980,229 B1	12/2005	Ebersole	
6,985,556 B2	1/2006	Shanmugavel et al.	
6,993,954 B1	2/2006	George et al.	
6,999,850 B2	2/2006	McDonald	
7,013,527 B2	3/2006	Thomas et al.	
7,024,278 B2	4/2006	Chiappetta et al.	
7,024,280 B2	4/2006	Parker et al.	
7,027,893 B2	4/2006	Perry et al.	
7,030,768 B2	4/2006	Wanie	
7,031,805 B2	4/2006	Lee et al.	
7,032,469 B2	4/2006	Bailey	
7,053,578 B2	5/2006	Diehl et al.	
7,054,716 B2	5/2006	McKee et al.	
7,055,210 B2	6/2006	Keppler et al.	
7,057,120 B2	6/2006	Ma et al.	
7,057,643 B2	6/2006	Iida et al.	
7,065,430 B2	6/2006	Naka et al.	
7,066,291 B2	6/2006	Martins et al.	
7,069,124 B1	6/2006	Whittaker et al.	
7,079,923 B2	7/2006	Abramson et al.	
7,085,623 B2	8/2006	Siegers	
7,085,624 B2	8/2006	Aldred et al.	
7,113,847 B2	9/2006	Chmura et al.	
7,133,746 B2	11/2006	Abramson et al.	
7,142,198 B2	11/2006	Lee	
7,148,458 B2	12/2006	Schell et al.	
7,155,308 B2	12/2006	Jones	
7,167,775 B2	1/2007	Abramson et al.	
7,171,285 B2	1/2007	Kim et al.	
7,173,391 B2	2/2007	Jones et al.	
7,174,238 B1	2/2007	Zweig	
7,188,000 B2	3/2007	Chiappetta et al.	
7,193,384 B1	3/2007	Norman et al.	
7,196,487 B2	3/2007	Jones et al.	
7,201,786 B2	4/2007	Wegelin et al.	
7,206,677 B2	4/2007	Hulden	
7,211,980 B1	5/2007	Bruemmer et al.	
7,225,500 B2	6/2007	Diehl et al.	
7,246,405 B2	7/2007	Yan	
7,248,951 B2	7/2007	Huldén	
7,275,280 B2	10/2007	Haegermarck et al.	
7,283,892 B1	10/2007	Boillot et al.	
7,288,912 B2	10/2007	Landry et al.	
7,318,248 B1	1/2008	Yan	

7,320,149 B1	1/2008	Huffman et al.
7,324,870 B2	1/2008	Lee
7,328,196 B2	2/2008	Peters
7,332,890 B2	2/2008	Cohen et al.
7,352,153 B2	4/2008	Yan
7,359,766 B2	4/2008	Jeon et al.
7,360,277 B2	4/2008	Moshenrose et al.
7,363,108 B2	4/2008	Noda et al.
7,388,879 B2	6/2008	Sabe et al.
7,389,166 B2	6/2008	Harwig et al.
7,408,157 B2	8/2008	Yan
7,418,762 B2	9/2008	Arai et al.
7,430,455 B2	9/2008	Casey et al.
7,430,462 B2	9/2008	Chiu et al.
7,441,298 B2	10/2008	Svendsen et al.
7,444,206 B2	10/2008	Abramson et al.
7,448,113 B2	11/2008	Jones et al.
7,459,871 B2	12/2008	Landry et al.
7,467,026 B2	12/2008	Sakagami et al.
7,474,941 B2	1/2009	Kim et al.
7,503,096 B2	3/2009	Lin
7,515,991 B2	4/2009	Egawa et al.
7,555,363 B2	6/2009	Augenbraun et al.
7,557,703 B2	7/2009	Yamada et al.
7,568,259 B2	8/2009	Yan
7,571,511 B2	8/2009	Jones et al.
7,578,020 B2	8/2009	Jaworski et al.
7,600,521 B2	10/2009	Woo
7,603,744 B2	10/2009	Reindle
7,617,557 B2	11/2009	Reindle
7,620,476 B2	11/2009	Morse et al.
7,636,982 B2	12/2009	Jones et al.
7,647,144 B2	1/2010	Haegermarck
7,650,666 B2	1/2010	Jang
7,660,650 B2	2/2010	Kawagoe et al.
7,663,333 B2	2/2010	Jones et al.
7,693,605 B2	4/2010	Park
7,706,917 B1	4/2010	Chiappetta et al.
7,765,635 B2	8/2010	Park
7,801,645 B2	9/2010	Taylor et al.
7,805,220 B2	9/2010	Taylor et al.
7,809,944 B2	10/2010	Kawamoto
7,849,555 B2	12/2010	Hahm et al.
7,853,645 B2	12/2010	Brown et al.
7,920,941 B2	4/2011	Park et al.
7,937,800 B2	5/2011	Yan
7,957,836 B2	6/2011	Myeong et al.
2001/0004719 A1	6/2001	Sommer
2001/0013929 A1	8/2001	Torsten
2001/0020200 A1	9/2001	Das et al.
2001/0025183 A1	9/2001	Shahidi
2001/0037163 A1	11/2001	Allard
2001/0043509 A1	11/2001	Green et al.
2001/0045883 A1	11/2001	Holdaway et al.
2001/0047231 A1	11/2001	Peless et al.
2001/0047895 A1	12/2001	De Fazio et al.
2002/0011367 A1	1/2002	Kolesnik
2002/0011813 A1	1/2002	Koselka et al.
2002/0016649 A1	2/2002	Jones
2002/0021219 A1	2/2002	Edwards
2002/0027652 A1	3/2002	Paromtchik et al.
2002/0036779 A1	3/2002	Kiyoi et al.
2002/0081937 A1	6/2002	Yamada et al.
2002/0095239 A1	7/2002	Wallach et al.
2002/0097400 A1	7/2002	Jung et al.
2002/0104963 A1	8/2002	Mancevski
2002/0108209 A1	8/2002	Peterson
2002/0112742 A1	8/2002	Bredo et al.
2002/0113973 A1	8/2002	Ge
2002/0116089 A1	8/2002	Kirkpatrick
2002/0120364 A1	8/2002	Colens
2002/0124343 A1	9/2002	Reed
2002/0153185 A1	10/2002	Song et al.
2002/0156556 A1	10/2002	Ruffner
2002/0159051 A1	10/2002	Guo
2002/0166193 A1	11/2002	Kasper
2002/0169521 A1	11/2002	Goodman et al.
2002/0173877 A1	11/2002	Zweig
2002/0189871 A1	12/2002	Won
2003/0009259 A1	1/2003	Hattori et al.
2003/0019071 A1	1/2003	Field et al.
2003/0023356 A1	1/2003	Keable
2003/0024986 A1	2/2003	Mazz et al.
2003/0025472 A1	2/2003	Jones et al.
2003/0028286 A1	2/2003	Glenn et al.
2003/0030399 A1	2/2003	Jacobs
2003/0058262 A1	3/2003	Sato et al.
2003/0060928 A1	3/2003	Abramson et al.
2003/0067451 A1	4/2003	Tagg et al.
2003/0097875 A1	5/2003	Lentz et al.
2003/0120389 A1	6/2003	Abramson et al.
2003/0124312 A1	7/2003	Autumn
2003/0126352 A1	7/2003	Barrett
2003/0137268 A1	7/2003	Papanikolopoulos et al.
2003/0146384 A1	8/2003	Logsdon et al.
2003/0192144 A1	10/2003	Song et al.
2003/0193657 A1	10/2003	Uomori et al.
2003/0216834 A1	11/2003	Allard
2003/0221114 A1	11/2003	Hino et al.
2003/0229421 A1	12/2003	Chmura et al.
2003/0229474 A1	12/2003	Suzuki et al.
2003/0233177 A1	12/2003	Johnson et al.
2003/0233870 A1	12/2003	Mancevski
2003/0233930 A1	12/2003	Ozick
2004/0016077 A1	1/2004	Song et al.
2004/0020000 A1	2/2004	Jones
2004/0030448 A1	2/2004	Solomon
2004/0030449 A1	2/2004	Solomon
2004/0030450 A1	2/2004	Solomon
2004/0030451 A1	2/2004	Solomon
2004/0030570 A1	2/2004	Solomon
2004/0030571 A1	2/2004	Solomon
2004/0031113 A1	2/2004	Wosewick et al.
2004/0049877 A1	3/2004	Jones et al.
2004/0055163 A1	3/2004	McCambridge et al.
2004/0068351 A1	4/2004	Solomon
2004/0068415 A1	4/2004	Solomon
2004/0068416 A1	4/2004	Solomon
2004/0074038 A1	4/2004	Im et al.
2004/0074044 A1	4/2004	Diehl et al.
2004/0076324 A1	4/2004	Burl et al.
2004/0083570 A1	5/2004	Song et al.
2004/0085037 A1	5/2004	Jones et al.
2004/0088079 A1	5/2004	Lavarec et al.
2004/0093122 A1	5/2004	Galibraith
2004/0098167 A1	5/2004	Yi et al.
2004/0111184 A1	6/2004	Chiappetta et al.
2004/0111821 A1	6/2004	Lenkiewicz et al.
2004/0113777 A1	6/2004	Matsuhira et al.
2004/0117064 A1	6/2004	McDonald
2004/0117846 A1	6/2004	Karaoguz et al.
2004/0118998 A1	6/2004	Wingett et al.
2004/0128028 A1	7/2004	Miyamoto et al.
2004/0133316 A1	7/2004	Dean
2004/0134336 A1	7/2004	Solomon
2004/0134337 A1	7/2004	Solomon
2004/0143919 A1	7/2004	Wilder
2004/0148419 A1	7/2004	Chen et al.
2004/0148731 A1	8/2004	Damman et al.
2004/0153212 A1	8/2004	Profio et al.
2004/0156541 A1	8/2004	Jeon et al.
2004/0158357 A1	8/2004	Lee et al.
2004/0181706 A1	9/2004	Chen et al.
2004/0187249 A1	9/2004	Jones et al.
2004/0187457 A1	9/2004	Colens
2004/0196451 A1	10/2004	Aoyama
2004/0200505 A1	10/2004	Taylor et al.
2004/0204792 A1	10/2004	Taylor et al.
2004/0210345 A1	10/2004	Noda et al.
2004/0210347 A1	10/2004	Sawada et al.
2004/0211444 A1	10/2004	Taylor et al.
2004/0221790 A1	11/2004	Sinclair et al.
2004/0236468 A1	11/2004	Taylor et al.
2004/0244138 A1	12/2004	Taylor et al.
2004/0255425 A1	12/2004	Arai et al.
2005/0000543 A1	1/2005	Taylor et al.
2005/0010330 A1	1/2005	Abramson et al.
2005/0010331 A1	1/2005	Taylor et al.

2005/0021181 A1	1/2005	Kim et al.
2005/0067994 A1	3/2005	Jones et al.
2005/0085947 A1	4/2005	Aldred et al.
2005/0137749 A1	6/2005	Jeon et al.
2005/0144751 A1	7/2005	Kegg et al.
2005/0150074 A1	7/2005	Diehl et al.
2005/0150519 A1	7/2005	Keppler et al.
2005/0154795 A1	7/2005	Kuz et al.
2005/0156562 A1	7/2005	Cohen et al.
2005/0163119 A1*	7/2005	Ito et al. 370/389
2005/0165508 A1	7/2005	Kanda et al.
2005/0166354 A1	8/2005	Uehigashi
2005/0166355 A1	8/2005	Tani
2005/0172445 A1	8/2005	Diehl et al.
2005/0183229 A1*	8/2005	Uehigashi 15/319
2005/0183230 A1	8/2005	Uehigashi
2005/0187678 A1	8/2005	Myeong et al.
2005/0192707 A1	9/2005	Park et al.
2005/0204717 A1	9/2005	Colens
2005/0209736 A1	9/2005	Kawagoe
2005/0211880 A1	9/2005	Schell et al.
2005/0212929 A1	9/2005	Schell et al.
2005/0213082 A1	9/2005	DiBernardo et al.
2005/0213109 A1	9/2005	Schell et al.
2005/0217042 A1	10/2005	Reindle
2005/0218852 A1	10/2005	Landry et al.
2005/0222933 A1	10/2005	Wesby
2005/0229340 A1	10/2005	Sawalski et al.
2005/0229355 A1	10/2005	Crouch et al.
2005/0235451 A1	10/2005	Yan
2005/0251292 A1	11/2005	Casey et al.
2005/0255425 A1	11/2005	Pierson
2005/0258154 A1	11/2005	Blankenship et al.
2005/0273967 A1	12/2005	Taylor et al.
2005/0288819 A1	12/2005	de Guzman
2006/0000050 A1	1/2006	Cipolla et al.
2006/0010638 A1	1/2006	Shimizu et al.
2006/0020369 A1	1/2006	Taylor et al.
2006/0020370 A1	1/2006	Abramson
2006/0021168 A1	2/2006	Nishikawa
2006/0025134 A1	2/2006	Cho et al.
2006/0037170 A1	2/2006	Shimizu
2006/0042042 A1	3/2006	Mertes et al.
2006/0044546 A1	3/2006	Lewin et al.
2006/0060216 A1	3/2006	Woo et al.
2006/0061657 A1	3/2006	Rew et al.
2006/0064828 A1	3/2006	Stein et al.
2006/0087273 A1	4/2006	Ko et al.
2006/0089765 A1	4/2006	Pack et al.
2006/0100741 A1	5/2006	Jung
2006/0119839 A1	6/2006	Bertin et al.
2006/0143295 A1	6/2006	Costa-Requena et al.
2006/0146776 A1	7/2006	Kim
2006/0190133 A1	8/2006	Konandreas et al.
2006/0190146 A1	8/2006	Morse et al.
2006/0196003 A1	9/2006	Song et al.
2006/0220900 A1	10/2006	Ceskutti et al.
2006/0259194 A1	11/2006	Chiu
2006/0259494 A1	11/2006	Watson et al.
2006/0288519 A1	12/2006	Jaworski et al.
2006/0293787 A1	12/2006	Kanda et al.
2007/0006404 A1	1/2007	Cheng et al.
2007/0017061 A1	1/2007	Yan
2007/0028574 A1	2/2007	Yan
2007/0032904 A1	2/2007	Kawagoe et al.
2007/0042716 A1	2/2007	Goodall et al.
2007/0043459 A1	2/2007	Abbott et al.
2007/0061041 A1	3/2007	Zweig
2007/0114975 A1	5/2007	Cohen et al.
2007/0150096 A1	6/2007	Yeh et al.
2007/0157415 A1	7/2007	Lee et al.
2007/0157420 A1	7/2007	Lee et al.
2007/0179670 A1	8/2007	Chiappetta et al.
2007/0226949 A1	10/2007	Hahm et al.
2007/0234492 A1	10/2007	Svendsen et al.
2007/0244610 A1	10/2007	Ozick et al.
2007/0250212 A1	10/2007	Halloran et al.
2007/0266508 A1	11/2007	Jones et al.
2008/0007203 A1	1/2008	Cohen et al.
2008/0039974 A1	2/2008	Sandin et al.
2008/0052846 A1	3/2008	Kapoor et al.
2008/0091304 A1	4/2008	Ozick et al.
2008/0184518 A1	8/2008	Taylor et al.
2008/0276407 A1	11/2008	Schnittman et al.
2008/0281470 A1	11/2008	Gilbert et al.
2008/0282494 A1	11/2008	Won et al.
2008/0294288 A1	11/2008	Yamauchi
2008/0302586 A1	12/2008	Yan
2008/0307590 A1	12/2008	Jones et al.
2009/0007366 A1	1/2009	Svendsen et al.
2009/0038089 A1	2/2009	Landry et al.
2009/0049640 A1	2/2009	Lee et al.
2009/0055022 A1	2/2009	Casey et al.
2009/0102296 A1	4/2009	Greene et al.
2009/0292393 A1	11/2009	Casey et al.
2010/0011529 A1	1/2010	Won et al.
2010/0049365 A1	2/2010	Jones et al.
2010/0063628 A1	3/2010	Landry et al.
2010/0107355 A1	5/2010	Won et al.
2010/0257690 A1	10/2010	Jones et al.
2010/0257691 A1	10/2010	Jones et al.
2010/0263158 A1	10/2010	Jones et al.
2010/0268384 A1	10/2010	Jones et al.
2010/0312429 A1	12/2010	Jones et al.

FOREIGN PATENT DOCUMENTS

DE	3317376 A1	11/1984
DE	3536907 C2	2/1989
DE	3404202 C2	12/1992
DE	199311014 U1	10/1993
DE	4414683 A1	10/1995
DE	4338841 C2	8/1999
DE	19849978	2/2001
DE	19849978 C2	2/2001
DE	102 42 257	4/2003
DE	102004038074.0	6/2005
DE	10357636 A1	7/2005
DE	102004041021	8/2005
DE	102004041021 B3	8/2005
DE	102005046813 A1	4/2007
DK	198803389 A	12/1988
EP	265542 A1	5/1988
EP	281085 A2	9/1988
EP	307381 A3	7/1990
EP	358628 A3	5/1991
EP	437024 A1	7/1991
EP	433697 A3	12/1992
EP	479273 A3	5/1993
EP	294101 B1	12/1993
EP	554978 A3	3/1994
EP	615719 A1	9/1994
EP	861629 A1	9/1998
EP	792726 B1	6/1999
EP	930040 A3	10/1999
EP	845237 B1	4/2000
EP	1018315 A1	7/2000
EP	1172719 A1	1/2002
EP	1228734 A3	6/2003
EP	1 331 537 A1	7/2003
EP	1 331 537 B1	7/2003
EP	1380245	1/2004
EP	1380246 A3	3/2005
EP	1553472 A1	7/2005
EP	1557730	7/2005
EP	1642522 A3	11/2007
ES	2238196	8/2005
ES	2238196 B1	11/2006
FR	2601443 B1	11/1991
FR	2 828 589	8/2001
GB	702 426	1/1954
GB	702426 A	1/1954
GB	2128842 B	4/1986
GB	2213047 A	8/1989
GB	2225221 A	5/1990
GB	2 283 838	5/1995
GB	2284957 A	6/1995
GB	2267360 B	12/1995
GB	2300082 B	9/1999

GB	2404330	B	7/2005	JP	7311041	A2	11/1995
GB	2417354	A	2/2006	JP	7313417	A	12/1995
JP	53021869	U	2/1978	JP	7319542	A2	12/1995
JP	53110257	A	9/1978	JP	8000393	B2	1/1996
JP	53110257	A2	9/1978	JP	8000393	Y2	1/1996
JP	943901	C	3/1979	JP	8016241	A2	1/1996
JP	57014726	A2	1/1982	JP	8016776	B	2/1996
JP	57064217	A	4/1982	JP	8016776	B2	2/1996
JP	59005315	B	2/1984	JP	8063229	A2	3/1996
JP	59033511	U	3/1984	JP	8083125	A	3/1996
JP	59094005	A	5/1984	JP	8083125	A2	3/1996
JP	59099308	U	7/1984	JP	08-089451		4/1996
JP	59112311	U	7/1984	JP	8089449	A	4/1996
JP	59033511	B	8/1984	JP	2520732	B2	5/1996
JP	59120124	U	8/1984	JP	8123548	A	5/1996
JP	59131668	U	9/1984	JP	08-152916		6/1996
JP	59164973	A	9/1984	JP	8152916	A2	6/1996
JP	59184917	A	10/1984	JP	8256960	A2	10/1996
JP	2283343	A2	11/1984	JP	8263137	A	10/1996
JP	59212924	A	12/1984	JP	8286741	A2	11/1996
JP	59226909	A	12/1984	JP	8286744	A2	11/1996
JP	60089213		5/1985	JP	8322774	A	12/1996
JP	60089213	U	6/1985	JP	8322774	A2	12/1996
JP	60211510	A	10/1985	JP	8335112	A	12/1996
JP	60259895	A	12/1985	JP	9043901	A	2/1997
JP	61023221	A2	1/1986	JP	9044240	A	2/1997
JP	61097712	A	5/1986	JP	9047413	A	2/1997
JP	61023221	B	6/1986	JP	9066855	A	3/1997
JP	62074018	A	4/1987	JP	9145309	A	6/1997
JP	62070709	U	5/1987	JP	9160644	A	6/1997
JP	62-120510		6/1987	JP	9160644	A2	6/1997
JP	62-154008		7/1987	JP	9-179625		7/1997
JP	62154008		7/1987	JP	9179625	A2	7/1997
JP	62164431	U	10/1987	JP	9179685	A2	7/1997
JP	62263507	A	11/1987	JP	9185410		7/1997
JP	62263508	A	11/1987	JP	9192069	A2	7/1997
JP	62189057	U	12/1987	JP	9204223	A2	8/1997
JP	63079623	A	4/1988	JP	9206258	A	8/1997
JP	63-183032		7/1988	JP	9206258	A2	8/1997
JP	63158032	A	7/1988	JP	9233712	A	9/1997
JP	63-241610		10/1988	JP	09251318		9/1997
JP	1162454	A	6/1989	JP	9251318	A	9/1997
JP	2-6312		1/1990	JP	9265319	A	10/1997
JP	2006312	U1	1/1990	JP	9269807	A	10/1997
JP	2026312	B	6/1990	JP	9269810	A	10/1997
JP	2283343	A	11/1990	JP	02555263	Y2	11/1997
JP	03-051023		3/1991	JP	9319431	A2	12/1997
JP	3051023	A2	3/1991	JP	9319432	A	12/1997
JP	3197758	A	8/1991	JP	9319434	A	12/1997
JP	3201903	A	9/1991	JP	9325812	A	12/1997
JP	4019586	B	3/1992	JP	10055215	A	2/1998
JP	4084921	A	3/1992	JP	10117973	A	5/1998
JP	5023269	B	4/1993	JP	10117973	A2	5/1998
JP	5091604	A2	4/1993	JP	10118963	A	5/1998
JP	5042076	U	6/1993	JP	10177414	A	6/1998
JP	5046246	U	6/1993	JP	10214114	A	8/1998
JP	5150827	A	6/1993	JP	10214114	A2	8/1998
JP	5150829	A	6/1993	JP	10228316		8/1998
JP	5046239	B	7/1993	JP	10240342	A2	9/1998
JP	5054620	U	7/1993	JP	10260727	A2	9/1998
JP	5040519	Y2	10/1993	JP	10295595	A	11/1998
JP	5257527	A	10/1993	JP	11015941	A	1/1999
JP	5257533	A	10/1993	JP	11065655	A2	3/1999
JP	5285861	A	11/1993	JP	11085269	A2	3/1999
JP	6003251	Y2	1/1994	JP	11102219	A2	4/1999
JP	6026312	U	4/1994	JP	11102220	A	4/1999
JP	6137828	A	5/1994	JP	11162454	A	6/1999
JP	6293095	A	10/1994	JP	11174145	A	7/1999
JP	06-327598		11/1994	JP	11175149	A	7/1999
JP	6105781	B	12/1994	JP	11178764	A	7/1999
JP	7059702	A2	3/1995	JP	11178765	A	7/1999
JP	7129239	A	5/1995	JP	11-508810		8/1999
JP	7059702	B	6/1995	JP	11212642	A	8/1999
JP	7222705	A	8/1995	JP	11212642	A2	8/1999
JP	7222705	A2	8/1995	JP	11213157	A	8/1999
JP	7270518	A	10/1995	JP	11-510935		9/1999
JP	7281742	A2	10/1995	JP	11248806	A	9/1999
JP	7281752	A	10/1995	JP	11282532	A	10/1999
JP	7-295636		11/1995	JP	11282533	A	10/1999

JP	11295412	A	10/1999	JP	2005230032	A	9/2005
JP	11346964	A2	12/1999	JP	2005245916	A	9/2005
JP	2000047728	A	2/2000	JP	2005296511	A	10/2005
JP	2000056006	A	2/2000	JP	2005346700	A2	12/2005
JP	2000056831	A	2/2000	JP	2005352707	A	12/2005
JP	2000066722	A	3/2000	JP	2006043071	A	2/2006
JP	2000075925	A	3/2000	JP	2006155274	A	6/2006
JP	10240343	A2	5/2000	JP	2006164223	A	6/2006
JP	2000275321	A	10/2000	JP	2006227673	A	8/2006
JP	2000353014	A	12/2000	JP	2006247467	A	9/2006
JP	2000353014	A2	12/2000	JP	2006260161	A	9/2006
JP	2001022443	A	1/2001	JP	2006293662	A	10/2006
JP	2001067588	A	3/2001	JP	2006296697	A	11/2006
JP	2001087182		4/2001	JP	2007034866	A	2/2007
JP	2001087182	A	4/2001	JP	2007213180	A	8/2007
JP	2001121455	A	5/2001	JP	04074285	B2	4/2008
JP	2001125641	A	5/2001	JP	2008-301878		12/2008
JP	2001216482	A	8/2001	JP	2009015611	A	1/2009
JP	2001-258807		9/2001	JP	2009-254603		11/2009
JP	2001265437	A	9/2001	JP	2010198552	A	9/2010
JP	2001-275908		10/2001	JP	2012-200461		10/2012
JP	2001289939	A	10/2001	WO	WO 95/26512		10/1995
JP	2001306170	A	11/2001	WO	WO9530887	A1	11/1995
JP	2001320781	A	11/2001	WO	WO9617258	A3	2/1997
JP	2001-525567		12/2001	WO	WO 97/15224		5/1997
JP	2002-78650		3/2002	WO	WO 97/40734		11/1997
JP	2002-204768		7/2002	WO	WO 97/41451		11/1997
JP	2002204769	A	7/2002	WO	WO9853456	A1	11/1998
JP	2002247510	A	8/2002	WO	WO9905580	A2	2/1999
JP	2002-532178		10/2002	WO	WO9916078	A1	4/1999
JP	3356170		10/2002	WO	WO 99/28800		6/1999
JP	2002-323925		11/2002	WO	WO 99/38056		7/1999
JP	2002333920	A	11/2002	WO	WO 99/38237		7/1999
JP	2002-355206		12/2002	WO	WO 99/43250		9/1999
JP	2002-360471		12/2002	WO	WO9959042	A1	11/1999
JP	2002-360482		12/2002	WO	WO 00/04430		1/2000
JP	2002360479	A	12/2002	WO	WO 00/36962		6/2000
JP	2002366227	A	12/2002	WO	WO 00/38026		6/2000
JP	2002369778	A	12/2002	WO	WO0038028	A1	6/2000
JP	2002369778	A2	12/2002	WO	WO0038029	A1	6/2000
JP	2003-10076		1/2003	WO	WO 00/78410		12/2000
JP	2003010076	A	1/2003	WO	WO 01/06904		2/2001
JP	2003010088	A	1/2003	WO	WO 01/06905		2/2001
JP	2003015740	A	1/2003	WO	WO0180703	A1	11/2001
JP	2003028528	A	1/2003	WO	WO0191623	A2	12/2001
JP	2003-5296		2/2003	WO	WO 02/39864		5/2002
JP	2003-036116		2/2003	WO	WO 02/39868		5/2002
JP	2003-38401		2/2003	WO	WO 02/058527		8/2002
JP	2003-38402		2/2003	WO	WO 02/062194		8/2002
JP	2003-505127		2/2003	WO	WO 02/067744		9/2002
JP	03375843	B2	2/2003	WO	WO 02/067745		9/2002
JP	2003047579	A	2/2003	WO	WO 02/071175		9/2002
JP	2003052596	A	2/2003	WO	WO 02/074150		9/2002
JP	2003-061882		3/2003	WO	WO 02/075356		9/2002
JP	2003084994	A	3/2003	WO	WO 02/075469		9/2002
JP	2003167628	A	6/2003	WO	WO 02/075470		9/2002
JP	2003180586	A	7/2003	WO	WO02067752	A1	9/2002
JP	2003180587	A	7/2003	WO	WO02069774	A1	9/2002
JP	2003186539	A	7/2003	WO	WO02075350	A1	9/2002
JP	2003190064	A	7/2003	WO	WO02081074	A1	10/2002
JP	2003190064	A2	7/2003	WO	WO 02/101477		12/2002
JP	2003241836	A	8/2003	WO	WO03015220	A1	2/2003
JP	2003262520	A	9/2003	WO	WO03024292	A2	3/2003
JP	2003285288	A	10/2003	WO	WO 03/026474		4/2003
JP	2003304992	A	10/2003	WO	WO 03/040845		5/2003
JP	2003-310489		11/2003	WO	WO 03/040846		5/2003
JP	2003310509	A	11/2003	WO	WO02069775	A3	5/2003
JP	2003330543	A	11/2003	WO	WO03040546	A1	5/2003
JP	2004123040	A	4/2004	WO	WO03062850	A2	7/2003
JP	2004148021	A	5/2004	WO	WO03062852	A1	7/2003
JP	2004160102	A	6/2004	WO	WO 2004/006034		1/2004
JP	2004166968	A	6/2004	WO	WO2004004533	A1	1/2004
JP	2004174228	A	6/2004	WO	WO2004004534	A1	1/2004
JP	2004198330	A	7/2004	WO	WO2004005956	A1	1/2004
JP	2004219185	A	8/2004	WO	WO2004058028	A2	1/2004
JP	2005118354	A	5/2005	WO	WO2005077244	A1	1/2004
JP	2005135400	A	5/2005	WO	WO2006068403	A1	1/2004
JP	2005211360	A	8/2005	WO	WO2004025947	A3	5/2004
JP	2005224265	A	8/2005	WO	WO2004043215	A1	5/2004

WO	WO2004/058028		7/2004
WO	WO2004/059409		7/2004
WO	WO2004058028		7/2004
WO	WO2005006935	A1	1/2005
WO	WO2005036292	A1	4/2005
WO	WO 2005/055795		6/2005
WO	WO2005055796	A2	6/2005
WO	WO2005076545	A1	8/2005
WO	WO2005077243	A1	8/2005
WO	WO2005081074	A1	9/2005
WO	WO2005082223	A1	9/2005
WO	WO2005083541	A1	9/2005
WO	WO2005098475	A1	10/2005
WO	WO2005098476	A1	10/2005
WO	WO2006046400	A1	5/2006
WO	WO2006/061133		6/2006
WO	WO2006073248	A1	7/2006
WO	WO2007036490	A3	5/2007
WO	WO2007065033	A2	6/2007
WO	WO2007137234	A2	11/2007

OTHER PUBLICATIONS

Jarosiewicz et al. "Final Report—Lucid", University of Florida, Departmetn of Electrical and Computer Engineering, EEL 5666—Intelligent Machine Design Laboratory, 50 pages, Aug. 4, 1999.

Jensfelt, et al. "Active Global Localization for a mobile robot using multiple hypothesis tracking", IEEE Transactions on Robots and Automation vol. 17, No. 5, pp. 748-760, Oct. 2001.

Jeong, et al. "An intelligent map-building system for indoor mobile robot using low cost photo sensors", SPIE vol. 6042 6 pages, 2005.

Kahney, "Robot Vacs are in the House," www.wired.com/news/technology/o,1282,59237,00.html, 6 pages, Jun. 18, 2003.

Karcher "Product Manual Download Karch", www.karcher.com, 17 pages, 2004.

Karcher "Karcher RoboCleaner RC 3000", www.robocleaner.de/english/screen3.html, 4 pages, Dec. 12, 2003.

Karcher USA "RC 3000 Robotics cleaner", www.karcher-usa.com, 3 pages, Mar. 18, 2005.

Karlsson et al., The vSLAM Algorithm for Robust Localization and Mapping, Proceedings of the 2005 IEEE International Conference on Robotics and Automation, Barcelona, Spain, pp. 24-29, Apr. 2005.

Karlsson, et al Core Technologies for service Robotics, IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2004), vol. 3, pp. 2979-2984, Sep. 28-Oct. 2, 2004.

King "Heplmate—TM—Autonomous mobile Robots Navigation Systems", SPIE vol. 1388 Mobile Robots pp. 190-198, 1990.

Kleinberg, The Localization Problem for Mobile Robots, Laboratory for Computer Science, Massachusetts Institute of Technology, 1994 IEEE, pp. 521-531, 1994.

Knight, et al., "Localization and Identification of Visual Landmarks", Journal of Computing Sciences in Colleges, vol. 16 Issue 4, 2001 pp. 312-313, May 2001.

Kolodko et al. "Experimental System for Real-Time Motion Estimation", Proceedings of the 2003 IEEE/ASME International Conference on Advanced Intelligent Mechatronics (AIM 2003), pp. 981-986, 2003.

Komoriya et al., Planning of Landmark Measurement for the Navigation of a Mobile Robot, Proceedings of the 1992 IEEE/RSJ International Cofnerence on Intelligent Robots and Systems, Raleigh, NC pp. 1476-1481, Jul. 7-10, 1992.

Koolatron "KOOLVAC—Owner's Manual", 13 pages.

Krotov, et al. "Digital Sextant", Downloaded from the internet at: http://www.cs.cmu.edu/~epk/ , 1 page, 1995.

Krupa et al. "Autonomous 3-D Positioning of Surgical Instruments in Robotized Laparoscopic Surgery Using Visual Servoing", IEEE Transactions on Robotics and Automation, vol. 19, No. 5, pp. 842-853, Oct. 5, 2003.

Kuhl, et al. "Self Localization in Environments using Visual Angles", VRCAI '04 Proceedings of the 2004 ACM SIGGRAPH international conference on Virtual Reality continuum and its applications in industry, pp. 472-475, 2004.

Kurth, "Range-Only Robot Localization and SLAM with Radio", http://www.ri.cmu.edu/pub_files/pub4/kurth_derek_2004_1/kurth_derek_2004_1.pdf. 60 pages, May 2004.

Lambrinos, et al. "A mobile robot employing insect strategies for navigation", http://www8.cs.umu.se/kurser/TDBD17/VT04/dl/Assignment%20Papers/lambrinos-RAS-2000.pdf, 38 pages, Feb. 19, 1999.

Lang et al. "Visual Measurement of Orientation Using Ceiling Features", 1994 IEEE, pp. 552-555, 1994.

Lapin, "Adaptive position estimation for an automated guided vehicle", SPIE vol. 1831 Mobile Robots VII, pp. 82-94, 1992.

LaValle et al. "Robot Motion Planning in a Changing, Partially Predictable Environment", 1994 IEEE International Symposium on Intelligent Control, Columbus, OH, pp. 261-266, Aug. 16-18, 1994.

Lee, et al. "Localization of a Mobile Robot Using the Image of a Moving Object", IEEE Transaction on Industrial Electronics, vol. 50, No. 3 pp. 612-619, Jun. 2003.

Lee, et al. "Development of Indoor Navigation system for Humanoid Robot Using Multi-sensors Integration", ION NTM, San Diego, CA pp. 798-805, Jan. 22-24, 2007.

Leonard, et al. "Mobile Robot Localization by tracking Geometric Beacons", IEEE Transaction on Robotics and Automation, vol. 7, No. 3 pp. 376-382, Jun. 1991.

Li et al. "Robost Statistical Methods for Securing Wireless Localization in Sensor Networks", Wireless Information Network Laboratory, Rutgers University.

Li et al. "Making a Local Map of Indoor Environments by Swiveling a Camera and a Sonar", Proceedings of the 1999 IEEE/RSJ International Conference on Intelligent Robots and Systems, pp. 954-959, 1999.

Lin, et al.. "Mobile Robot Navigation Using Artificial Landmarks", Journal of robotics System 14(2). pp. 93-106, 1997.

Linde "Dissertation, "On Aspects of Indoor Localization"" https://eldorado.tu-dortmund.de/handle/2003/22854, University of Dortmund, 138 pages, Aug. 28, 2006.

Lumelsky, et al. "An Algorithm for Maze Searching with Azimuth Input", 1994 IEEE International Conference on Robotics and Automation, San Diego, CA vol. 1, pp. 111-116, 1994.

Luo et al., "Real-time Area-Covering Operations with Obstacle Avoidance for Cleaning Robots," 2002, IEeE, p. 2359-2364.

Ma "Thesis: Documentation on Northstar", California Institute of Technology, 14 pages, May 17, 2006.

Madsen, et al. "Optimal landmark selection for triangulation of robot position", Journal of Robotics and Autonomous Systems vol. 13 pp. 277-292, 1998.

Martishevcky, "The Accuracy of point light target coordinate determination by dissectoral tracking system", SPIE vol. 2591 pp. 25-30.

Matsutek Enterprises Co. Ltd "Automatic Rechargeable Vacuum Cleaner", http://matsutek.manufacturer.globalsources.com/si/6008801427181/pdtl/Home-vacuum/10 . . . , Apr. 23, 2007.

McGillem, et al. "Infra-red Lacation System for Navigation and Autonomous Vehicles", 1988 IEEE International Conference on Robotics and Automation, vol. 2, pp. 1236-1238, Apr. 24-29, 1988.

McGillem,et al. "A Beacon Navigation Method for Autonomous Vehicles", IEEE Transactions on Vehicular Technology, vol. 38, No. 3, pp. 132-139, Aug. 1989.

Michelson "Autonomous Navigation", 2000 Yearbook of Science & Technology, McGraw-Hill, New York, ISBN 0-07-052771-7, pp. 28-30, 1999.

Miro, et al. "Towards Vision Based Navigation in Large Indoor Environments", Proceedings of the IEEE/RSJ International Conference on Intelligent Robots and Systems, Beijing, China, pp. 2096-2102, Oct. 9-15, 2006.

MobileMag "Samsung Unveils High-tech Robot Vacuum Cleaner", http://www.mobilemag.com/content/100/102/C2261/, 4 pages, Mar. 18, 2005.

Monteiro, et al. "Visual Servoing for Fast Mobile Robot: Adaptive Estimation of Kinematic Parameters", Proceedings of the IECON '93., International Conference on Industrial Electronics, Maui, HI, pp. 1588-1593, Nov. 15-19, 1993.

Moore, et al. A simple Map—bases Localization strategy using range measurements, SPIE vol. 5804 pp. 612-620, 2005.

Munich et al. "SIFT-ing Through Features with ViPR", IEEE Robotics & Automation Magazine, pp. 72-77, Sep. 2006.

Munich et al. "ERSP: A Software Platform and Architecture for the Service Robotics Industry", Intelligent Robots and Systems, 2005. (IROS 2005), pp. 460-467, Aug. 2-6, 2005.

Nam, et al. "Real-Time Dynamic Visual Tracking Using PSD Sensors and extended Trapezoidal Motion Planning", Applied Intelligence 10, pp. 53-70, 1999.

Nitu et al. "Optomechatronic System for Position Detection of a Mobile Mini-Robot", IEEE Ttransactions on Industrial Electronics, vol. 52, No. 4, pp. 969-973, Aug. 2005.

On Robo "Robot Reviews Samsung Robot Vacuum (VC-RP30W)", www.onrobo.com/reviews/AT_Home/vacuum_cleaners/ on00vcrb30rosam/index.htm.. 2 pages, 2005.

InMach "Intelligent Machines", www.inmach.de/inside.html, 1 page , Nov. 19, 2008.

Innovation First "2004 EDU Robot Controller Reference Guide", http://www.ifirobotics.com, 13 pgs., Mar. 1, 2004.

Wolf et al. "Robust Vision-based Localization for Mobile Robots Using an Image Retrieval System Based on Invariant Features", Proceedings of the 2002 IEEE International Conference on Robotics & Automation, Washington, D.C. pp. 359-365, May 2002.

Wolf et al. "Robust Vision-Based Localization by Combining an Image-Retrieval System with Monte Carol Localization", IEEE Transactions on Robotics, vol. 21, No. 2, pp. 208-216, Apr. 2005.

Wong "EIED Online>> Robot Business", ED Online ID# 13114, 17 pages, Jul. 2006.

Yamamoto et al. "Optical Sensing for Robot Perception and Localization", 2005 IEEE Workshop on Advanced Robotics and its Social Impacts, pp. 14-17, 2005.

Yata et al. "Wall Following Using Angle Information Measured by a Single Ultrasonic Transducer", Proceedings of the 1998 IEEE, International Conference on Robotics & Automation, Leuven, Belgium, pp. 1590-1596, May 1998.

Yun, et al. "Image-Based Absolute Positioning System for Mobile Robot Navigation", IAPR International Workshops SSPR, Hong Kong, pp. 261-269, Aug. 17-19, 2006.

Yun, et al. "Robust Positioning a Mobile Robot with Active Beacon Sensors", Lecture Notes in Computer Science, 2006, vol. 4251, pp. 890-897, 2006.

Yuta, et al. "Implementation of an Active Optical Range sensor Using Laser Slit for In-Door Intelligent Mobile Robot", IEE/RSJ International workshop on Intelligent Robots and systems (IROS 91) vol. 1, Osaka, Japan, pp. 415-420, Nov. 3-5, 1991.

Zha et al. "Mobile Robot Localization Using Incomplete Maps for Change Detection in a Dynamic Environment", Advanced Intelligent Mechatronics '97. Final Program and Abstracts., IEEE/ASME International Conference, pp. 110, Jun. 16-20, 1997.

Zhang, et al. "A Novel Mobile Robot Localization Based on Vision", SPIE vol. 6279, 6 pages, Jan. 29, 2007.

Euroflex Intellegente Monstre Mauele (English only except).

Roboking—not just a vacuum cleaner, a robot! Jan. 21, 2004, 5 pages.

SVET Computers—New Technologies—Robot vacuum cleaner, 1 page.

Popco.net Make your digital life http://www.popco.net/zboard/view.php?id=tr_review&no=40 accessed Nov. 1, 2011.

Matsumura Camera Online Shop http://www.rakuten.co.jp/matsucame/587179/711512/ accessed Nov. 1, 2011.

Dyson's Robot Vacuum Cleaner—the DC06, May 2, 2004 http://www.gizmag.com/go/1282/ accessed Nov. 11, 2011.

Electrolux Trilobite, http://www.electrolux-ui.com:8080/2002%5C822%5C833102EN.pdf 10 pages.

Electrolux Trilobite, Time to enjoy life, 38 pages http://www.robocon.co.kr/trilobite/Presentation_Trilobite_Kor_030104.ppt accessed Dec. 22, 2011.

Facts on the Trilobite http://www.frc.ri.cmu.edu/~hpm/talks/Extras/trilobite.desc.html 2 pages accessed Nov. 1, 2011.

Euroflex Jan. 1, 2006 http://www.euroflex.tv/novita_dett.php?id=15 1 page accessed Nov. 1, 2011.

FloorBotics, VR-8 Floor Cleaning Robot, Product Description for Manuafacturers, http://www.consensus.com.au/SoftwareAwards/CSAarchive/CSA2004/CSAart04/FloorBot/F.

Friendly Robotics, 18 pages http://www.robotsandrelax.com/PDFs/RV400Manual.pdf accessed Dec. 22, 2011.

Its eye, 2003 www.hitachi.co.jp/rd/pdf/topics/hitac2003_10.pdf 2 pages.

Hitachi, May 29, 2003 http://www.hitachi.co.jp/New/cnews/hl_030529_hl_030529.pdf 8 pages.

Robot Buying Guide, LG announces the first robotic vacuum cleaner for Korea, Apr. 21, 2003 http://robotbg.com/news/2003/04/22/Ig_announces_the_first_robotic_vacu.

CleanMate 365, Intelligent Automatic Vacuum Cleaner, Model No. QQ-1, User Manual www.metapo.com/support/user_manual.pdf 11 pages.

UBOT, cleaning robot capable of wiping with a wet duster, http://us.aving.net/news/view.php?articleId=23031, 4 pages accessed Nov. 1, 2011.

Taipei Times, Robotic vacuum by Matsuhita about ot undergo testing, Mar. 26, 2002 http://www.taipeitimes.com/News/worldbiz/archives/2002/03/26/0000129338 accessed.

Tech-on! http://techon.nikkeibp.co.jp/members/01db/200203/1006501/, 4 pages, accessed Nov. 1, 2011.

http://ascii.jp/elem/000/000/330/330024/.

IT media http://www.itmedia.co.jp/news/0111/16/robofesta_m.html accessed Nov. 1, 2011.

Yujin Robotics, an intelligent cleaning robot 'iclebo Q' AVING USA http://us.aving.net/news/view.php?articleId=7257, 8 pages accessed Nov. 4, 2011.

Special Reports, Vacuum Cleaner Robot Operated in Conjunction with 3G Celluar Phone vol. 59, No. 9 (2004) 3 pages http://www.toshiba.co.jp/tech/review/2004/09/59_0.

Toshiba Corporation 2003, http://warp.ndl.go.jp/info:ndljp/pid/258151/www.soumu.go.jp/joho_tsusin/policyreports/chousa/netrobot/pdf/030214_1_33_a.pdf 16 pages.

http://www.karcher.de/versions/intg/assets/video/2_4_robo_en.swf. Accessed Sep. 25, 2009.

McLurkin "The Ants: A community of Microrobots", Paper submitted for requirements of BSEE at MIT, May 12, 1995.

Grumet "Robots Clean House", Popular Mechanics, Nov. 2003.

McLurkin Stupid Robot Tricks: A Behavior-based Distributed Algorithm Library for Programming Swarms of Robots, Paper submitted for requirements of BSEE at MIT, May 2004.

Kurs et al, Wireless Power transfer via Strongly Coupled Magnetic Resonances, Downloaded from www.sciencemag.org , Aug. 17, 2007.

OnRobo "Samsung Unveils Its Multifunction Robot Vacuum", www.onrobo.com/enews/0210/samsung_vacuum.shtml, 3 pages, Mar. 18, 2005.

Pages et al. "Optimizing Plane-to-Plane Positioning Tasks by Image-Based Visual Servoing and Structured Light", IEEE Transactions on Robotics, vol. 22, No. 5, pp. 1000-1010, Oct. 2006.

Pages et al. "A camera-projector system for robot positioning by visual servoing", Proceedings of the 2006 Conference on Computer Vision and Pattern Recognition Workshop (CVPRW06), 8 pages, Jun. 17-22, 2006.

Pages, et al. "Robust decoupled visual servoing based on structured light", 2005 IEEE/RSJ Int. Conf. on Intelligent Robots and Systems, pp. 2676-2681, 2005.

Park et al. "A Neural Network Based Real-Time Robot Tracking Controller Using Position Sensitive Detectors," IEEE World Congress on Computational Intelligence., 1994 IEEE International Conference on Neutral Networks, Orlando, Florida pp. 2754-2758, Jun. 27-Jul. 2, 1994.

Park, et al. "Dynamic Visual Servo Control of Robot Manipulators using Neutral Networks", The Korean Institute Telematics and Electronics, vol. 29-B, No. 10, pp. 771-779, Oct. 1992.

Paromtchik "Toward Optical Guidance of Mobile Robots".

Paromtchik, et al. "Optical Guidance System for Multiple mobile Robots", Proceedings 2001 ICRA. IEEE International Conference on Robotics and Automation, vol. 3, pp. 2935-2940 (May 21-26, 2001).

Penna, et al. "Models for Map Building and Navigation", IEEE Transactions on Systems. Man. and Cybernetics. vol. 23 No. 5, pp. 1276-1301, Sep./Oct. 1993.

Pirjanian "Reliable Reaction", Proceedings of the 1996 IEEE/SICE/RSJ International Conference on Multisensor Fusion and Integration for Intelligent Systems, pp. 158-165, 1996.

Pirjanian "Challenges for Standards for consumer Robotics", IEEE Workshop on Advanced Robotics and its Social impacts, pp. 260-264, Jun. 12-15, 2005.

Pirjanian et al. "Distributed Control for a Modular, Reconfigurable Cliff Robot", Proceedings of the 2002 IEEE International Conference on Robotics & Automation, Washington, D.C. pp. 4083-4088, May 2002.

Pirjanian et al. "Representation and Execution of Plan Sequences for Multi-Agent Systems", Proceedings of the 2001 IEEE/RSJ International Conference on Intelligent Robots and Systems, Maui, Hawaii, pp. 2117-2123, Oct. 29-Nov. 3, 2001.

Pirjanian et al. "Multi-Robot Target Acquisition using Multiple Objective Behavior Coordination", Proceedings of the 2000 IEEE International Conference on Robotics & Automation, San Francisco, CA, pp. 2696-2702, Apr. 2000.

Pirjanian et al. "A decision-theoretic approach to fuzzy behavior coordination", 1999 IEEE International Symposium on Computational Intelligence in Robotics and Automation, 1999. CIRA '99., Monterey, CA, pp. 101-106, Nov. 8-9, 1999.

Pirjanian et al. "Improving Task Reliability by Fusion of Redundant Homogeneous Modules Using Voting Schemes", Proceedings of the 1997 IEEE International Conference on Robotics and Automation, Albuquerque, NM, pp. 425-430, Apr. 1997.

Pressler et al., "A Short History of Cleaning Robots", Autonomous Robots 9, 211-226, 2000, 16 pages.

Radio Frequency Identification: Tracking ISS Consumables, Author Unknown, 41 pages (NPL0127).

Remazeilles, et al. "Image based robot navigation in 3D environments", Proc. of SPIE, vol. 6052, pp. 1-14, Dec. 6, 2005.

Rives, et al. "Visual servoing based on ellipse features", SPIE vol. 2056 Intelligent Robots and Computer Vision pp. 356-367, 1993.

Robotics World Jan. 2001: "A Clean Sweep" (Jan. 2001).

Ronnback "On Methods for Assistive Mobile Robots", http://www.openthesis.org/documents/methods-assistive-mobile-robots-595019.html, 218 pages, Jan. 1, 2006.

Roth-Tabak, et al. "Environment Model for mobile Robots Indoor Navigation", SPIE vol. 1388 Mobile Robots pp. 453-463, 1990.

Sadath M Malik et al. "Virtual Prototyping for Conceptual Design of a Tracked Mobile Robot". Electrical and Computer Engineering, Canadian Conference on, IEEE, PI. May 1, 2006, pp. 2349-2352.

Sahin, et al. "Development of a Visual Object Localization Module for Mobile Robots", 1999 Third European Workshop on Advanced Mobile Robots, (Eurobot '99), pp. 65-72, 1999.

Salomon, et al. "Low-Cost Optical Indoor Localization system for Mobile Objects without Image Processing", IEEE Conference on Emerging Technologies and Factory Automation, 2006. (ETFA '06), pp. 629-632, Sep. 20-22, 2006.

Sato "Range Imaging Based on Moving Pattern Light and Spatio-Temporal Matched Filter", Proceedings International Conference on Image Processing, vol. 1., Lausanne, Switzerland, pp. 33-36, Sep. 16-19, 1996.

Schenker, et al. "Lightweight rovers for Mars science exploration and sample return", Intelligent Robots and Computer Vision XVI, SPIE Proc. 3208, pp. 24-36, 1997.

Sebastian Thrun, Learning Occupancy Grid Maps With Forward Sensor Models, School of Computer Science, Carnegie Mellon University, pp. 1-28.

Shimoga et al. "Touch and Force Reflection for Telepresence Surgery", Engineering in Medicine and Biology Society, 1994. Engineering Advances: New Opportunities for Biomedical Engineers. Proceedings of the 16th Annual International Conference of the IEEE, Baltimore, MD, pp. 1049-1050, 1994.

Sim, et al "Learning Visual Landmarks for Pose Estimation", IEEE International Conference on Robotics and Automation, vol. 3, Detroit, MI, pp. 1972-1978, May 10-15, 1999.

Sobh et al. "Case Studies in Web-Controlled Devices and Remote Manipulation", Automation Congress, 2002 Proceedings of the 5th Biannual World, pp. 435-440, Dec. 10, 2002.

Stella, et al. "Self-Location for Indoor Navigation of Autonomous Vehicles", Part of the SPIE conference on Enhanced and Synthetic Vision SPIE vol. 3364 pp. 298-302, 1998.

Summet "Tracking Locations of Moving Hand-held Displays Using Projected Light", Pervasive 2005, LNCS 3468 pp. 37-46 (2005).

Svedman et al. "Structure from Stereo Vision using Unsynchronized Cameras for Simultaneous Localization and Mapping", 2005 IEEE/RSJ International Conference on Intelligent Robots and Systems, pp. 2993-2998, 2005.

Takio et al. "Real-Time Position and Pose Tracking Method of Moving Object Using Visual Servo System", 47th IEEE International Symposium on Circuits and Systems, pp. 167-170, 2004.

Teller "Pervasive pose awareness for people, Objects and Robots", http://www.ai.mit.edu/lab/dangerous-ideas/Spring2003/teller-pose.pdf, 6 pages, Apr. 30, 2003.

Terada et al. "An Acquisition of the Relation between Vision and Action using Self-Organizing Map and Reinforcement Learning", 1998 Second International Conference on Knowledge-Based Intelligent Electronic Systems, Adelaide, Australiam pp. 429-434, Apr. 21-23, 1998.

The Sharper Image "e-Vac Robotic Vacuum, S1727 Instructions"www.sharperimage.com, 18 pages.

The Sharper Image "Robotic Vacuum Cleaner—Blue" www.Sharperimage.com, 2 pages, Mar. 18, 2005.

The Sharper Image "E Vac Robotic Vacuum", www.sharperiamge.com/us/en/templates/products/pipmorework1printable.jhtml, 2 pages, Mar. 18, 2005.

TheRobotStore.com "Friendly Robotics Robotic Vacuum RV400—The Robot Store", www.therobotstore.com/s.nl/sc.9/category.-109/it.A/id.43/.f, 1 page, Apr. 20, 2005.

TotalVac.com RC3000 RoboCleaner website Mar. 18, 2005.

Trebi-Ollennu et al. "Mars Rover Pair Cooperatively Transporting a Long Payload", Proceedings of the 2002 IEEE International Conference on Robotics & Automation, Washington, D.C. pp. 3136-3141, May 2002.

Tribelhorn et al., "Evaluating the Roomba: A low-cost, ubiquitous platform for robotics research and education," 2007, IEEE, p. 1393-1399.

Tse et al. "Design of a Navigation System for a Household Mobile Robot Using Neural Networks", Department of Manufacturing Engg. & Engg. Management, City University of Hong Kong, pp. 2151-2156, 1998.

UAMA (Asia) Industrial Co., Ltd. "RobotFamily", 2005.

Watanabe et al. "Position Estimation of Mobile Robots With Internal and External Sensors Using Uncertainty Evolution Technique", 1990 IEEE International Conference on Robotics and Automation, Cincinnati, OH, pp. 2011-2016, May 13-18, 1990.

Watts "Robot, boldly goes where no man can", The Times—pp. 20, Jan. 1985.

Wijk et al. "Triangulation-Based Fusion of Sonar Data with Application in Robot Pose Tracking ", IEEE Transactions on Robotics and Automation, vol. 16, No. 6, pp. 740-752, Dec. 2000.

Examination report dated Jul. 15, 2011 from corresponding U.S. Appl. No. 12/687,464.

Borges et al. "Optimal Mobile Robot Pose Estimation Using Geometrical Maps", IEEE Transactions on Robotics and Automation, vol. 18, No. 1, pp. 87-94, Feb. 2002.

Braunstingl et al. "Fuzzy Logic Wall Following of a Mobile Robot Based on the Concept of General Perception" ICAR '95, 7th International Conference on Advanced Robotics, Sant Feliu De Guixols, Spain, pp. 367-376, Sep. 1995.

Bulusu, et al. "Self Configuring Localization systems: Design and Experimental Evaluation", ACM Transactions on Embedded Computing Systems vol. 3 No. 1 pp. 24-60, 2003.

Caccia, et al. "Bottom-Following for Remotely Operated Vehicles", 5th IFAC conference, Alaborg, Denmark, pp. 245-250 Aug. 1, 2000.

Chae, et al. "StarLITE: A new artificial landmark for the navigation of mobile robots", http://www.irc.atr.jp/jk-nrs2005/pdf/Starlite.pdf, 4 pages, 2005.

Chamberlin et al. "Team 1: Robot Locator Beacon System" NASA Goddard SFC, Design Proposal, 15 pages, Feb. 17, 2006.

Champy "Physical management of IT assets in Data Centers using RFID technologies", RFID 2005 University, Oct. 12-14, 2005 (NPL0126).

Chiri "Joystick Control for Tiny OS Robot", http://www.eecs.berkeley.edu/Programs/ugrad/superb/papers2002/chiri.pdf. 12 pages, Aug. 8, 2002.

Christensen et al. "Theoretical Methods for Planning and Control in Mobile Robotics" 1997 First International Conference on Knowledge-Based Intelligent Electronic Systems, Adelaide, Australia, pp. 81-86, May 21-27, 1997.

Andersen et al., "Landmark based navigation strategies", SPIE Conference on Mobile Robots XIII, SPIE vol. 3525, pp.

Clerentin, et al. "A localization method based on two omnidirectional perception systems cooperation" Proc of IEEE International Conference on Robotics & Automation, San Francisco, CA vol. 2, pp. 1219-1224, Apr. 2000.

Corke "High Performance Visual serving for robots end-point control". SPIE vol. 2056 Intelligent robots and computer vision 1993.

Cozman et al. "Robot Localization using a Computer Vision Sextant", IEEE International Midwest Conference on Robotics and Automation, pp. 106-111, 1995.

D'Orazio, et al. "Model based Vision System for mobile robot position estimation", SPIE vol. 2058 Mobile Robots VIII, pp. 38-49, 1992.

De Bakker, et al. "Smart PSD—array for sheet of light range imaging", Proc. of SPIE vol. 3965, pp. 1-12, May 15, 2000.

Desaulniers, et al. "An Efficient Algorithm to find a shortest path for a car-like Robot", IEEE Transactions on robotics and Automation vol. 11 No. 6, pp. 819-828, Dec. 1995.

Dorfmüller-Ulhaas "Optical Tracking From User Motion to 3D Interaction", http://www.cg.tuwien.ac.at/research/publications/2002/Dorfmueller-Ulhaas-thesis, 182 pages, 2002.

Dorsch, et al. "Laser Triangulation: Fundamental uncertainty in distance measurement", Applied Optics, vol. 33 No. 7, pp. 1306-1314, Mar. 1, 1994.

Dudek, et al. "Localizing a Robot with Minimum Travel" Proceedings of the sixth annual ACM-SIAM symposium on Discrete algorithms, vol. 27 No. 2 pp. 583-604, Apr. 1998.

Dulimarta, et al. "Mobile Robot Localization in Indoor Environment", Pattern Recognition, vol. 30, No. 1, pp. 99-111, 1997.

EBay "Roomba Timer -> Timed Cleaning—Floorvac Robotic Vacuum", Cgi.ebay.com/ws/eBayISAPI.dll? viewitem&category=43526&item=4375198387&rd=1, 5 pages, Apr. 20, 2005.

Electrolux "Welcome to the Electrolux trilobite" www.electroluxusa.com/node57.asp?currentURL=node142.asp%3F, 2 pages, Mar. 18, 2005.

Eren, et al. "Accuracy in position estimation of mobile robots based on coded infrared signal transmission", Proceedings: Integrating Intelligent Instrumentation and Control, Instrumentation and Measurement Technology Conference, 1995. IMTC/95. pp. 548-551, 1995.

Eren, et al. "Operation of Mobile Robots in a Structured Infrared Environment", Proceedings. 'Sensing, Processing, Networking', IEEE Instrumentation and Measurement Technology Conference, 1997 (IMTC/97), Ottawa, Canada vol. 1, pp. 20-25, May 19-21, 1997.

Barker, "Navigation by the Stars—Ben Barker 4th Year Project" Power point pp. 1-20.

Becker, et al. "Reliable Navigation Using Landmarks" IEEE International Conference on Robotics and Automation, 0-7803-1965-6, pp. 401-406, 1995.

Benayad-Cherif, et al., "Mobile Robot Navigation Sensors" SPIE vol. 1831 Mobile Robots, VII, pp. 378-387, 1992.

Facchinetti, Claudio et al. "Using and Learning Vision-Based Self-Positioning for Autonomous Robot Navigation", ICARCV '94, vol. 3 pp. 1694-1698, 1994.

Betke, et al., "Mobile Robot localization using Landmarks" Proceedings of the IEEE/RSJ/GI International Conference on Intelligent Robots and Systems '94 "Advanced Robotic Systems and the Real World" (IROS '94), vol.

Facchinetti, Claudio et al. "Self-Positioning Robot Navigation Using Ceiling Images Sequences", ACCV '95, 5 pages, Dec. 5-8, 1995.

Fairfield, Nathaniel et al. "Mobile Robot Localization with Sparse Landmarks", SPIE vol. 4573 pp. 148-155, 2002.

Favre-Bulle, Bernard "Efficient tracking of 3D—Robot Position by Dynamic Triangulation", IEEE Instrumentation and Measurement Technology Conference IMTC 98 Session on Instrumentation and Measurement in Robotics, vol. 1, pp. 446-449, May 18-21, 1998.

Fayman "Exploiting Process Integration and Composition in the context of Active Vision", IEEE Transactions on Systems, Man, and Cybernetics—Part C: Application and reviews, vol. 29 No. 1, pp. 73-86, Feb. 1999.

Florbot GE Plastics Image (1989-1990).

Franz, et al. "Biomimetric robot navigation", Robotics and Autonomous Systems vol. 30 pp. 133-153, 2000.

Friendly Robotics "Friendly Robotic—Friendly Vac, Robotic Vacuum Cleaner", www.friendlyrobotics.com/vac.htm. 5 pages Apr. 20, 2005.

Fuentes, et al. "Mobile Robotics 1994", University of Rochester. Computer Science Department, TR 588, 44 pages, Dec. 7, 1994.

Bison, P et al., "Using a structured beacon for cooperative position estimation" Robotics and Autonomous Systems vol. 29, No. 1, pp. 33-40, Oct. 1999.

Fukuda, et al. "Navigation System based on Ceiling Landmark Recognition for Autonomous mobile robot", 1995 IEEE/RSJ International Conference on Intelligent Robots and Systems 95. 'Human Robot Interaction and Cooperative Robots', Pittsburgh, PA, pp. 1466/1471, Aug. 5-9, 1995.

Gionis "A hand-held optical surface scanner for environmental Modeling and Virtual Reality", Virtual Reality World, 16 pages 1996.

Goncalves et al. "A Visual Front-End for Simultaneous Localization and Mapping", Proceedings of the 2005 IEEE International Conference on Robotics and Automation, Barcelona, Spain, pp. 44-49, Apr. 2005.

Gregg et al. "Autonomous Lawn Care Applications", 2006 Florida Conference on Recent Advances in Robotics, FCRAR 2006, pp. 1-5, May 25-26, 2006.

Hamamatsu "SI PIN Diode S5980, S5981 S5870—Multi-element photodiodes for surface mounting", Hamatsu Photonics, 2 pages Apr. 2004.

Hammacher Schlemmer "Electrolux Trilobite Robotic Vacuum" www.hammacher.com/publish/71579.asp? promo=xsells, 3 pages, Mar. 18, 2005.

Haralick et al. "Pose Estimation from Corresponding Point Data", IEEE Transactions on systems, Man, and Cybernetics, vol. 19, No. 6, pp. 1426-1446, Nov. 1989.

Hausler "About the Scaling Behaviour of Optical Range Sensors", Fringe '97, Proceedings of the 3rd International Workshop on Automatic Processing of Fringe Patterns, Bremen, Germany, pp. 147-155, Sep. 15-17, 1997.

Blaasvaer, et al. "AMOR—An Autonomous Mobile Robot Navigation System", Proceedings of the IEEE International Conference on Systems, Man, and Cybernetics, pp. 2266-2271, 1994.

Hoag, et al. "Navigation and Guidance in interstellar space", ACTA Astronautica vol. 2, pp. 513-533 , Feb. 14, 1975.

Huntsberger et al. "CAMPOUT: A Control Architecture for Tightly Coupled Coordination of Multirobot Systems for Planetary Surface Exploration", IEEE Transactions on Systems, Man, and Cybernetics—Part A: Systems and Humans, vol. 33, No. 5, pp. 550-559, Sep. 2003.

Iirobotics.com "Samsung Unveils Its Multifunction Robot Vacuum", www.iirobotics.com/webpages/hotstuff.php? ubre=111, 3 pages, Mar. 18, 2005.

Andersen et al., "Landmark based navigation strategies", SPIE Conference on Mobile Robots XIII, SPIE vol. 3525, pp. 170-181, Jan. 8, 1999.

Ascii, Mar. 25, 2002, http://ascii.jp/elem/000/000/330/330024/ accessed Nov. 1, 2011.

Certified copy of U.S. Appl. No. 60/605,066 as provided to WIPO in PCT/US2005/030422, corresponding to U.S. National Stage Entry U.S. Appl. No. 11/574,290, U.S. publication 2008/0184518, filed Aug. 27, 2004.

Certified copy of U.S. Appl. No. 60/605,181 as provided to WIPO in PCT/US2005/030422, corresponding to U.S. National Stage Entry U.S. Appl. No. 11/574,290, U.S. publication 2008/0184518, filed Aug. 27, 2004.

Derek Kurth, "Range-Only Robot Localization and SLAM with Radio", http://www.ri.cmu.edu/pub_files/pub4/kurth_derek_2004_1/kurth_derek_2004_1.pdf. 60 pages, May 2004, accessed Jul. 27, 2012.

Electrolux Trilobite, Jan. 12, 2001, http://www.electrolux-ui. com:8080/2002%5C822%5C833102EN.pdf, accessed Jul. 2, 2012, 10 pages.

Florbot GE Plastics, 1989-1990, 2 pages, available at http://www. fuseid.com/, accessed Sep. 27, 2012.

Gregg et al., "Autonomous Lawn Care Applications," 2006 Florida Conference on Recent Advances in Robotics, Miami, Florida, May 25-26, 2006, Florida International University, 5 pages.

Hitachi 'Feature', http://kadenfan.hitachi.co.jp/robot/feature/feature.html, 1 page, Nov. 19, 2008.

Hitachi, http://www.hitachi.co.jp/New/cnews/hi__030529__hi__030529.pdf , 8 pages, May 29, 2003.

Home Robot—UBOT; Microbotusa.com, retrieved from the WWW at www.microrobotusa.com, accessed Dec. 2, 2008.

King and Weiman, "Helpmate™ Autonomous Mobile Robots Navigation Systems," SPIE vol. 1388 Mobile Robots, pp. 190-198 (1990).

Li et al. "Robust Statistical Methods for Securing Wireless Localization in Sensor Networks," Information Procesing in Sensor Networks, 2005, Fourth International Symposium on, pp. 91-98, Apr. 2005.

Martishevcky, "The Accuracy of point light target coordinate determination by dissectoral tracking system", SPIE vol. 2591, pp. 25-30, Oct. 23, 2005.

Maschinemarkt Würzburg 105, Nr. 27, pp. 3, 30, Jul. 5, 1999.

Miwako Doi "Using the symbiosis of human and robots from approaching Research and Development Center," Toshiba Corporation, 16 pages, available at http://warp.ndl.go.jp/info:ndljp/pid/258151/www.soumu.go.jp/joho__tsusin/policyreports/chousa/netrobot/pdf/030214__1__33__a.pdf, Feb. 26, 2003.

Paromtchik "Toward Optical Guidance of Mobile Robots," Proceedings of the Fourth World Multiconference on Systemics, Cybermetics and Informatics, Orlando, FL, USA, Jul. 23, 2000, vol. IX, pp. 44-49, available at http://emotion.inrialpes.fr/~paromt/infos/papers/paromtchik:asama:sci:2000.ps.gz, accessed Jul. 3, 2012.

Roboking—not just a vacuum cleaner, a robot!, Jan. 21, 2004, infocom.uz/2004/01/21/robokingne-prosto-pyilesos-a-robot/, accessed Oct. 10, 2011, 7 pages.

Sebastian Thrun, "Learning Occupancy Grid Maps With Forward Sensor Models," Autonomous Robots 15, 111-127, Sep. 1, 2003.

SVET Computers—New Technologies—Robot Vacuum Cleaner, Oct. 1999, available at http://www.sk.rs/1999/10/sknt01.html, accessed Nov. 1, 2011.

Written Opinion of the International Searching Authority, PCT/US2004/001504, Aug. 20, 2012, 9 pages.

Cameron Morland, Autonomous Lawn Mower Control, Jul. 24, 2002.

Doty, Keith L et al, "Sweep Strategies for a Sensory-Driven, Behavior-Based Vacuum Cleaning Agent" AAAI 1993 Fall Symposium Series Instantiating Real-World Agents Research Triangle Park, Raleigh, NC, Oct. 22-24, 1993, pp. 1-6.

Electrolux designed for the well-lived home, website: http://www.electroluxusa.com/node57.as[?currentURL=node142.asp%3F, acessed Mar. 18, 2005.

eVac Robotic Vacuum S1727 Instruction Manual, Sharper Image Corp, Copyright 2004.

Everyday Robots, website: http://www.everydayrobots.com/index.php?option=content&task=view&id=9, accessed Apr. 20, 2005.

Facts on the Trilobite webpage: "http://trilobiteelectroluxse/presskit__en/node11335asp?print=yes&pressID=" accessed Dec. 12, 2003.

Friendly Robotics Robotic Vacuum RV400—The Robot Store website: http://www.therobotstore.com/s.nl/sc.9/category,-109/it.A/id.43/.f, accessed Apr. 20, 2005.

Gat, Erann, Robust Low-computation Sensor-driven Control for Task-Directed Navigation, Proceedings of the 1991 IEEE, International Conference on Robotics and Automation, Sacramento, California, Apr. 1991, pp. 2484-2489.

Hitachi: News release: The home cleaning robot of the autonomous movement type (experimental machine) is developed, website: http://www.i4u.com/japanreleases/hitachirobot.htm., accessed Mar. 18, 2005.

Kärcher Product Manual Download webpage: "http://wwwkarchercom/bta/downloadenshtml?ACTION=SELECTTEILENR&ID=rc3000&submitButtonName=Select+Product+Manual" and associated pdf file "5959-915enpdf (47 MB) English/English" accessed Jan. 21, 2004.

Karcher RC 3000 Cleaning Robot—user manual Manufacturer: Alfred-Karcher GmbH & Co, Cleaning Systems, Alfred Karcher-Str 28-40, PO Box 160, D-71349 Winnenden, Germany, Dec. 2002.

Kärcher RoboCleaner RC 3000 Product Details webpages: "http://wwwrobocleanerde/english/screen3html" through "... screen6html" accessed Dec. 12, 2003.

Karcher USA, RC3000 Robotic Cleaner, website: http://www.karcher-usa.com/showproducts.php?op=view__prod&param1=143&param2=&param3=, accessed Mar. 18, 2005, 6 pgs.

koolvac Robotic Vacuum Cleaner Owner's Manual, Koolatron, Undated.

NorthStar Low-Cost, Indoor Localization, Evolution robotics, Powering Intelligent Products.

Put Your Roomba . . . on "Automatic" Roomba Timer> Timed Cleaning-Floorvac Robotic Vacuum webpages: http://cgi.ebay.com/ws/eBayISAPI.dll?ViewItem&category=43575198387&rd=1, accessed Apr. 20, 2005.

Put Your Roomba . . . on "Automatic" webpages: "http://www.acomputeredge.com/roomba," accessed Apr. 20, 2005.

RoboMaid Sweeps Your Floors So You Won't Have to, the Official Site, website: http://www.thereobomaid.com/, acessed Mar. 18, 2005.

Robot Review Samsung Robot Vacuum (VC-RP30W), website: http://www.onrobo.com/reviews/At__Home/Vacuun__Cleaners/on00vcrp30rosam/index.htm, accessed Mar. 18, 2005.

Robotic Vacuum Cleaner-Blue, website: http://www.sharperimage.com/us/en/catalog/productview.jhtml?sku=S1727BLU, accessed Mar. 18, 2005.

Schofield, Monica, "Neither Master nor Slave" A Practical Study in the Development and Employment of Cleaning Robots, Emerging Technologies and Factory Automation, 1999 Proceedings EFA'99 1999 7th IEEE International Conference on Barcelona, Spain Oct. 18-21, 1999, pp. 1427-1434.

Wired News: Robot Vacs Are in the House, website: http://www.wired.com/news/print/0,1294,59237,00.html, accessed Mar. 18, 2005.

Zoombot Remote Controlled Vaccum-RV-500 New Roomba 2, website: http://cgi.ebay.com/ws/eBayISAPI.dll?ViewItem&category=43526&item=4373497618&rd=1, accessed Apr. 20, 2005.

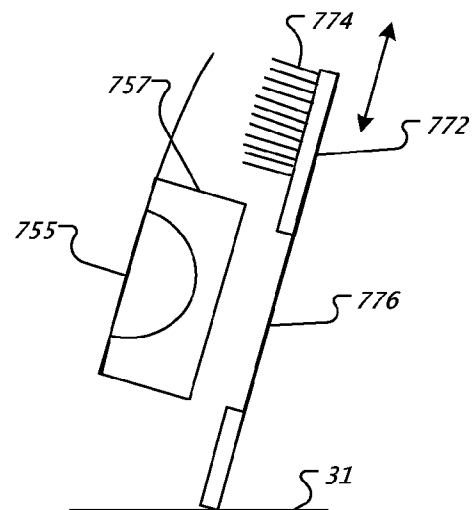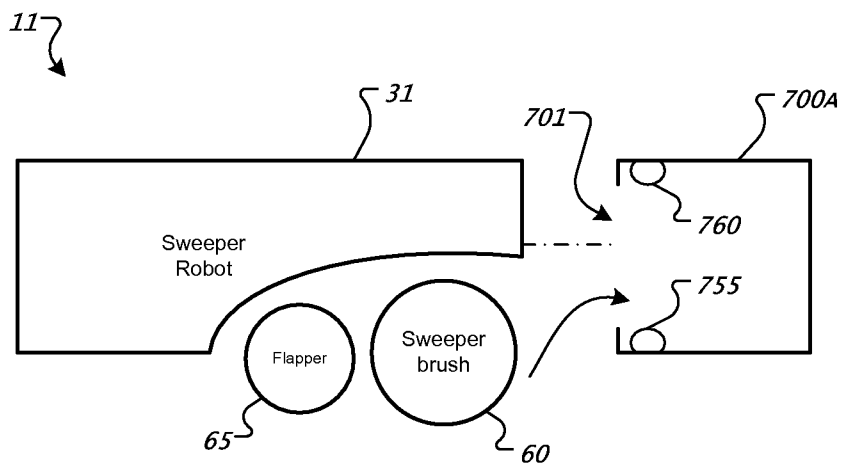Office Action dated Aug. 17, 2010 for corresponding application EP 07783998.3.

* cited by examiner

FIG. 1A
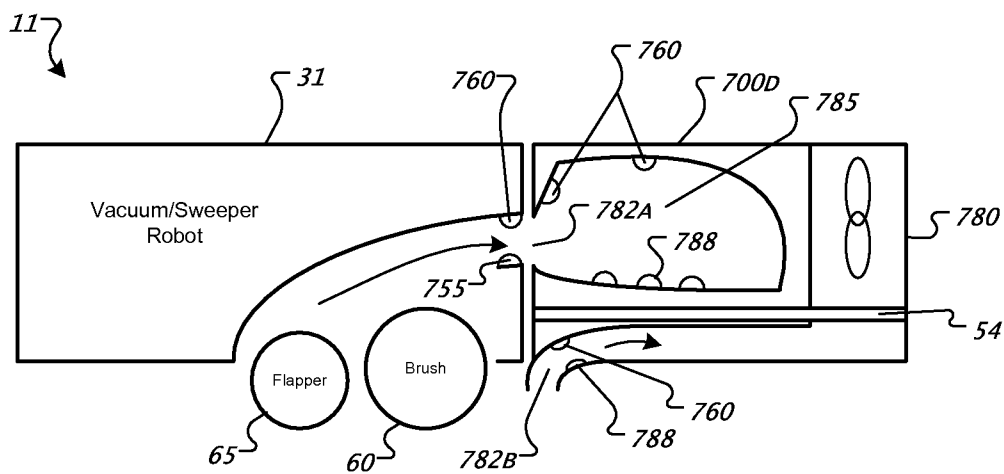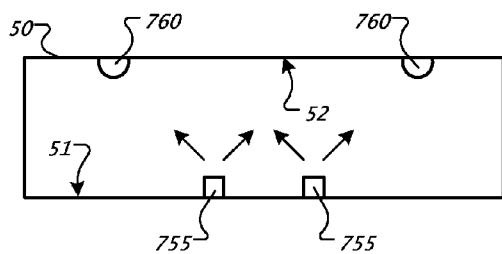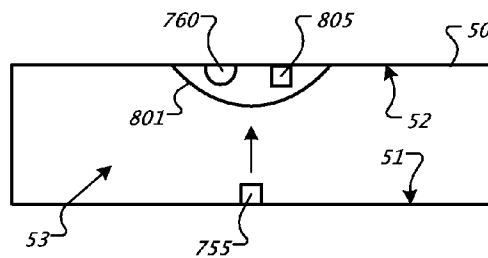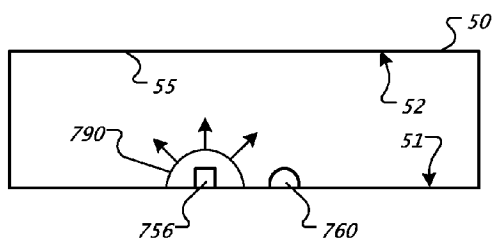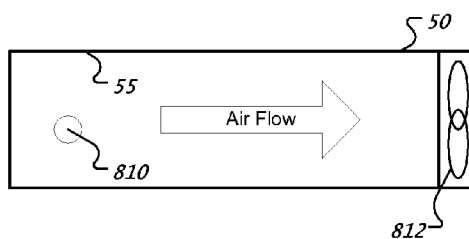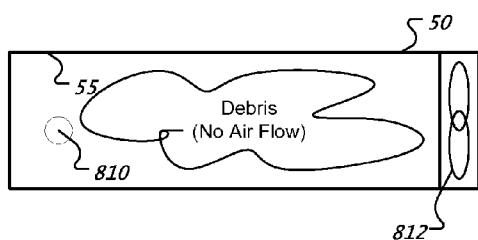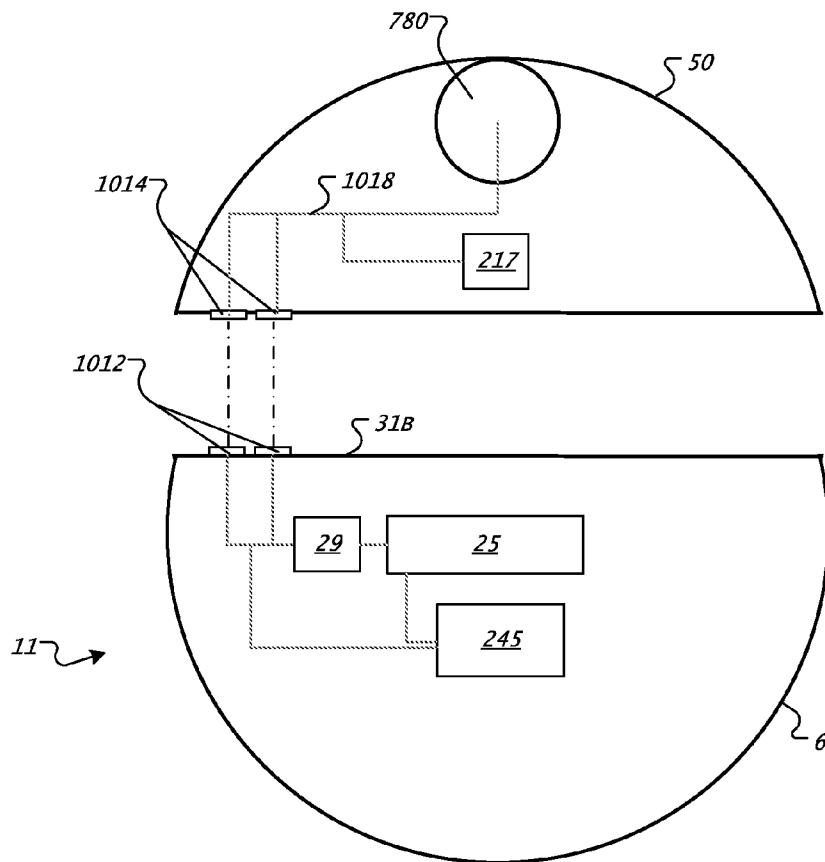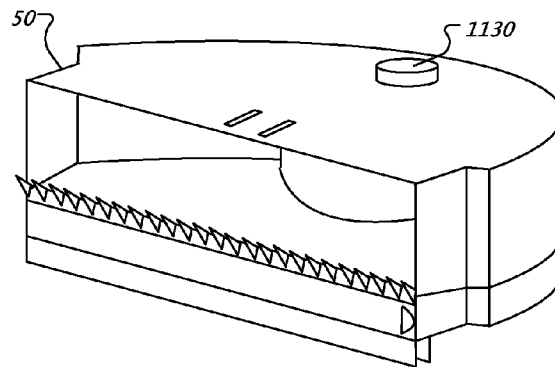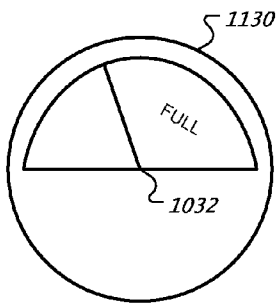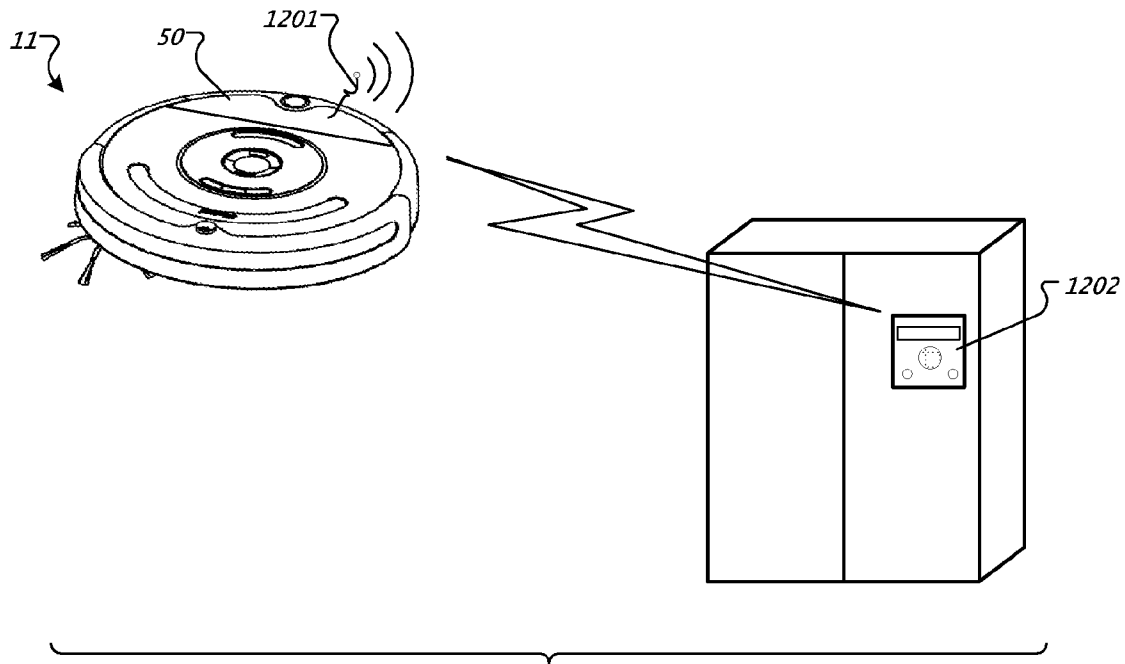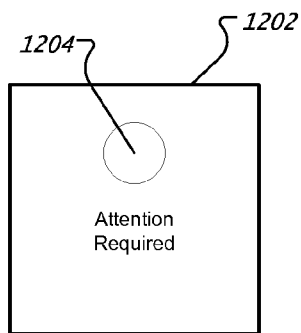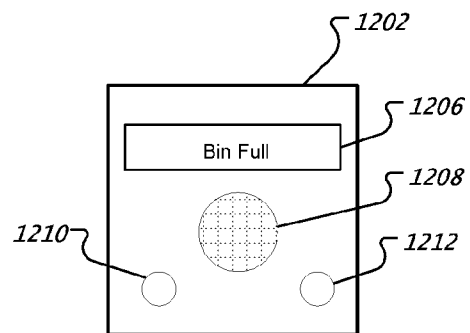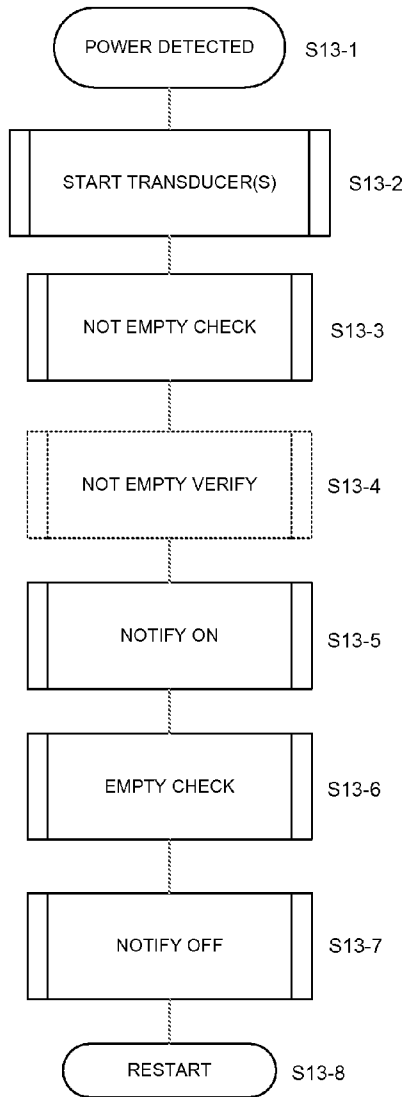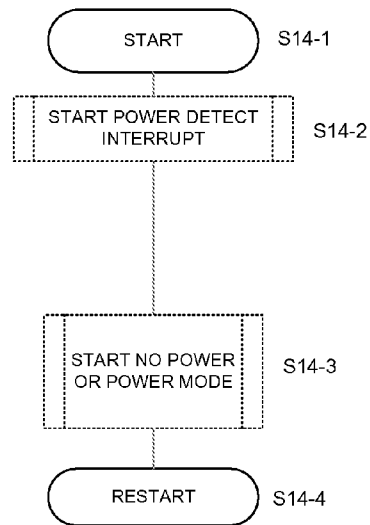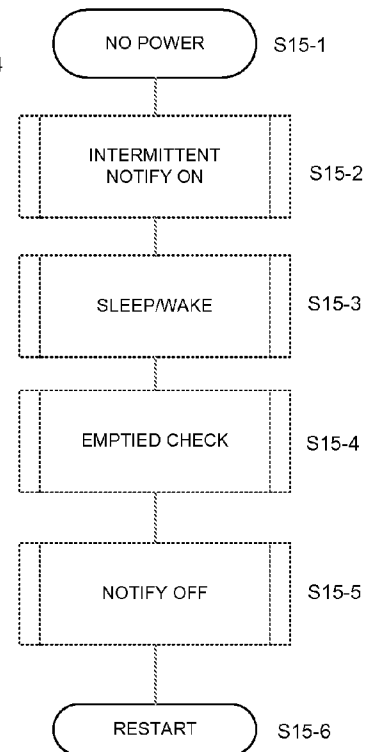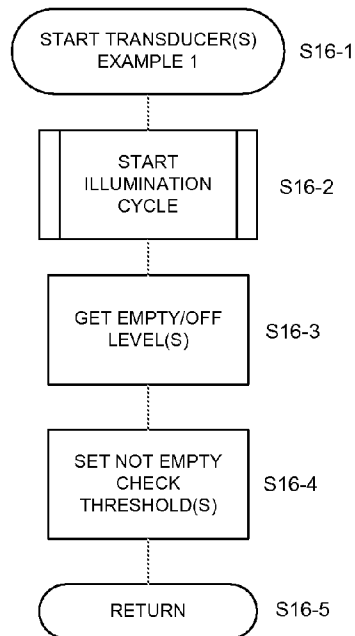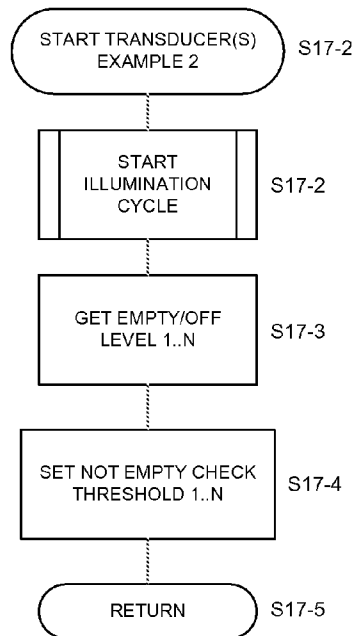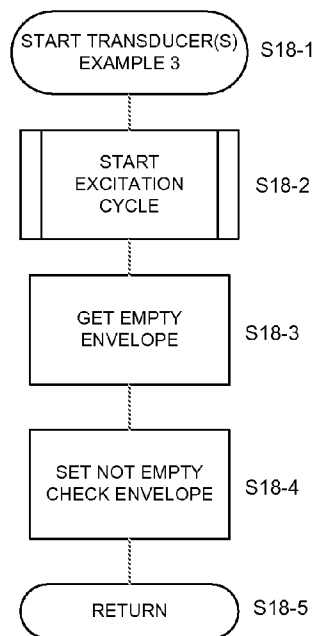

FIG. 1B

FIG. 1C

FIG. 2

FIG. 3A

FIG. 3B

FIG. 3C

FIG. 3D

FIG. 3E

300F

312F

310F

380

FIG. 3F

300G

312G

310G

380   380

FIG. 3G

400A

415

405A

420   425   430

410A

FIG. 4A

400B

482A

482B

460

450

452   480

54

470A   470B

465

FIG. 4B

400C

31

460

450

466

60

65

474 472 476 477

FIG. 4C

400D

31

460

450

467

60

65

473 474 477 476

FIG. 4D

NXX

460

450

466

474 472

60A 60B

FIG. 4E

FIG. 5A

FIG. 5B

FIG. 6A

FIG. 6B

FIG. 6C

FIG. 7A

FIG. 7B

FIG. 7C

FIG. 7D

FIG. 7E

FIG. 7F

FIG. 7G

FIG. 7H

FIG. 8A

FIG. 8B

FIG. 8C

FIG. 8D

FIG. 8E

11

902

FIG. 9A

902

904

1001

FIG. 9B

780

50

1014

1018

217

1012

31B

11

29

25

245

6

FIG. 10A

FIG. 10B

FIG. 11A

FULL

FIG. 11B   FIG. 11C   FIG. 11D

11
50
1201
1202

FIG. 12A

1204
1202

Attention
Required

FIG. 12B

1202
1206

Bin Full

1208
1210
1212

FIG. 12C

1250

11

FIG. 12D

POWER DETECTED   S13-1

START TRANSDUCER(S)   S13-2

NOT EMPTY CHECK   S13-3

NOT EMPTY VERIFY   S13-4

NOTIFY ON   S13-5

EMPTY CHECK   S13-6

NOTIFY OFF   S13-7

RESTART   S13-8

FIG. 13

START   S14-1

START POWER DETECT INTERRUPT   S14-2

START NO POWER OR POWER MODE   S14-3

RESTART   S14-4

FIG. 14

NO POWER   S15-1

INTERMITTENT NOTIFY ON   S15-2

SLEEP/WAKE   S15-3

EMPTIED CHECK   S15-4

NOTIFY OFF   S15-5

RESTART   S15-6

FIG. 15

START TRANSDUCER(S) EXAMPLE 1   S16-1

START ILLUMINATION CYCLE   S16-2

GET EMPTY/OFF LEVEL(S)   S16-3

SET NOT EMPTY CHECK THRESHOLD(S)   S16-4

RETURN   S16-5

FIG. 16

START TRANSDUCER(S) EXAMPLE 2   S17-2

START ILLUMINATION CYCLE   S17-2

GET EMPTY/OFF LEVEL 1..N   S17-3

SET NOT EMPTY CHECK THRESHOLD 1..N   S17-4

RETURN   S17-5

FIG. 17

START TRANSDUCER(S) EXAMPLE 3   S18-1

START EXCITATION CYCLE   S18-2

GET EMPTY ENVELOPE   S18-3

SET NOT EMPTY CHECK ENVELOPE   S18-4

RETURN   S18-5

FIG. 18

START TRANSDUCER(S) EXAMPLE 4   S19-1

START TRANSDUCER(S)   S19-2

GET EMPTY WAVEFORM/SIGNAL   S19-3

SET NOT EMPTY WAVEFORM/SIGNAL CHARACTERISTIC   S19-4

RETURN   S19-5

FIG. 19

START TRANSDUCER(S) EXAMPLE 5   S20-1

SET NOT EMPTY CHECK PROCESS/LOGIC   S20-2

RETURN   S20-3

FIG. 20

NOT EMPTY CHECK EXAMPLE 1   S21-2

MEASURE RECEIVED ILLUMINATION   S21-2

RECEIVED > THRESHOLD?   S21-3

RETURN   S21-4

FIG. 21

NOT EMPTY CHECK EXAMPLE 2   S22-1

MEASURE RECEIVED ILLUMINATION 1..N   S22-2

1..N RECEIVED > 1..N THRESHOLD(S)?   S22-3

RETURN   S22-4

FIG. 22

NOT EMPTY CHECK EXAMPLE 3   S23-1

TEST CHARACTERISTIC OF RECEIVED SIGNAL   S23-2

CHARACTERISTIC PASSED?   S23-3

RETURN   S23-4

FIG. 23

NOT EMPTY CHECK EXAMPLE 4   S24-1

PROCESS RECEIVED SIGNAL, TEST AS PROCESSED   S24-2

PASSED?   S24-3

RETURN   S24-4

FIG. 24

NOT EMPTY VERIFY EXAMPLE 1   S25-1

START SUSTAIN TIMER   S25-2

RECEIVED STILL > THRESHOLD(S)?   S25-3

TIMER ELAPSED?   S25-4

RETURN   S25-5

FIG. 25

NOT EMPTY VERIFY EXAMPLE 2   S26-1

START SUSTAIN TIMER   S26-2

1..N RECEIVED STILL > 1..N THRESHOLDS?   S26-3

TIMER ELAPSED?   S26-4

RETURN   S26-5

FIG. 26

NOT EMPTY VERIFY EXAMPLE 1   S27-1

START SUSTAIN TIMER   S27-2

1..N RECEIVED STILL > 1..N THRESHOLDS?   S27-3

RESTART

TIMER ELAPSED?   S27-4

RETURN   S27-5

FIG. 27

NOT EMPTY CHECK EXAMPLE 3   S28-1

CHECK SECONDARY SENSOR/ CONDITION   S28-2

ALSO DETECTS NOT FULL?   S28-3

RESTART

RETURN   S28-4

FIG. 28

MONITOR BIN
ON ROBOT

START
ILLUMINATION
CYCLE   S29-1

THRESHOLDS AT **CHECK**   S29-2

CALIBRATE/ SET
THRESHOLDS   S29-3

MEASURE RECEIVED ILLUMINATION
1..N   S29-4

NO

1..N RECEIVED ALL > 1..N
THRESHOLD(S)?   S29-5

YES

PRESUMED FULL,
START VERIFY TIMER   S29-6

CALIBRATE/ SET
THRESHOLDS   S29-7

NO

1..N RECEIVED ALL > 1..N
THRESHOLD(S)?   S29-8

YES

TIMER ELAPSED OR MAXIMUM?   NO

S29-9

YES

NOTIFY ON   S29-10

CHANGE ILLUM. CYCLE   S29-11

THRESHOLDS AT **VERIFY**   S29-12

CALIBRATE/ SET
THRESHOLDS   S29-13

NO

1..N RECEIVED ANY < 1..N
THRESHOLD(S)?   S29-14

YES

NOTIFY OFF   S29-15

RESTART   S29-16

FIG. 29

Initialize Timer (set counter to 5 minutes and decrement each second)   S30-1

Initialize sensor cycle   S30-2

S30-3

Run Sensor cycle

Poll All triggered?   S30-4

Yes

No

Reset counter   S30-5

Turn off bin full indicator if on   S30-6

Timer Completed?   S30-7

No

Yes

Turn on "bin full" indicator   S30-8

Increase light threshold (i.e. from 20% to 50%)   S30-9

FIG. 30

Initialize start time, set gradient to 0, etc.   S31-1

Check Status   S31-2

Is start-time already recorded?   S31-6

No

Running in cleaning mode?   S31-3

No

Yes

Record end-time (set end=current time   S31-7

Yes

Is start time already recorded   S31-4

Yes

No

Calculate accumulated cleaning mode time (end time minus start time)   S31-8

Record start time, set start=current time   S31-5

Add to grand total   S31-9

Grand-Total milestone?   S31-10

No

Yes

Increment Threshold   S31-11

FIG. 31

FIG. 32

COVERAGE ROBOTS AND ASSOCIATED CLEANING BINS

CROSS-REFERENCE TO RELATED APPLICATIONS

This U.S. patent application claims priority under 35 U.S.C. §119(e) to U.S. provisional patent applications 60/747,791, filed on May 19, 2006, 60/803,504, filed on May 30, 2006, and 60/807,442, filed on Jul. 14, 2006. The entire contents of the aforementioned applications are hereby incorporated by reference.

TECHNICAL FIELD

This disclosure relates to autonomous coverage robots and associated cleaning bins.

BACKGROUND

Autonomous robots are robots which can perform desired tasks in unstructured environments without continuous human guidance. Many kinds of robots are autonomous to some degree. Different robots can be autonomous in different ways. An autonomous coverage robot traverses a work surface without continuous human guidance to perform one or more tasks. In the field of home, office and/or consumer-oriented robotics, mobile robots that perform household functions such as vacuum cleaning, floor washing, patrolling, lawn cutting and other such tasks have been widely adopted.

SUMMARY

In one aspect, an autonomous coverage robot includes a chassis, a drive system mounted on the chassis and configured to maneuver the robot, and a cleaning assembly carried by the chassis. The cleaning assembly includes a cleaning assembly housing and at least one driven sweeper brush rotatably coupled to the cleaning assembly housing. The robot includes a controller carried by the chassis and a removable sweeper bin attached to the chassis. The sweeper bin is configured to receive debris agitated by the driven sweeper brush. The sweeper bin includes an emitter disposed on an interior surface of the bin and a receiver disposed remotely from the emitter on the interior surface of the bin. The receiver is configured to receive a signal emitted by the emitter. The emitter and the receiver are disposed such that a threshold level of accumulation of debris in the sweeper bin blocks the receiver from receiving emissions from the emitter. The robot includes a bin controller disposed in the sweeper bin and monitoring a signal from the detector and initiating a bin full routine upon determining a bin debris accumulation level requiring service.

Implementations of this aspect of the disclosure may include one or more of the following features. The cleaning bin is removably attached to the chassis. In some implementations, a diffuser is positioned over the emitter to diffuse the emitted signal. The receiver receives the diffused emissions. Accumulation of debris in the bin at least partially blocks diffused emissions from being received by the receiver. The emitter may include an infrared light emitter diffused by a translucent plastic sheet. In some examples, the emitter is disposed on a first interior lateral surface of the bin and the receiver is disposed on an opposing, second interior lateral surface of the bin. The emitter and the receiver may be arranged for a determination of debris accumulation within substantially an entire volume of the bin. In some implemen-

tations, the coverage robot bin-full detection system includes a human perceptible indicator providing an indication that autonomous operation may be interrupted for bin servicing. The cleaning bin may include a vacuum assembly having an at least partially separate entrance path into the bin. In some examples, the cleaning bin includes a plurality of teeth disposed substantially along a mouth of the bin between a sweeper bin portion and a vacuum bin portion housing the vacuum assembly. The teeth are configured to strip debris from the rotating sweeper brush and the debris is allowed to accumulate in the sweeper bin portion.

In another aspect, a coverage robot bin-full detection system includes a cleaning bin housing configured to be received by a cleaning robot and a bin capacity sensor system carried by the cleaning bin housing. The bin capacity sensor system includes at least one signal emitter disposed on an interior surface of the cleaning bin housing and at least one signal detector disposed on the interior surface of the cleaning bin housing. The detector is configured to receive a signal emitted by the emitter. The coverage robot bin-full detection system includes a controller carried by the cleaning bin housing and a remote indicator in wireless communication with the controller. The controller monitors a signal from the detector and determines a cleaning service requirement. The remote indicator provides an indication of the cleaning service requirement determined by the controller.

Implementations of this aspect of the disclosure may include one or more of the following features. In some implementations, the cleaning bin housing defines a sweeper bin portion and a vacuum bin portion. The cleaning bin housing may include a vacuum assembly housed by the vacuum bin portion. The emitter may be an infrared light emitter. In some implementations, the controller is configured to determine a robot stuck condition and communicate the robot stuck condition to the wireless remote indicator. The remote indicator may be configured to communicate commands to the bin controller. The bin controller may communicate with a controller of the robot.

In yet another aspect, a method of detecting fullness of a cleaning bin of an autonomous coverage robot includes determining an empty bin threshold signal value by reading a signal received from a bin-fullness detection system while the cleaning bin is empty. After a predetermined period of time, the method includes detecting a present bin signal value by reading the signal from the detection system. The method includes comparing the empty bin threshold signal value with the present bin signal value to determine a signal value difference. Then the method includes, in response to determining that the signal difference is greater than a predetermined amount, activating a bin full indicator.

Implementations of this aspect of the disclosure may include one or more of the following features. The method may include periodically determining the check bin signal and the signal difference, wherein the indicator is activated when the check bin signals is greater than the empty bin threshold signal. The indicator maybe activated when multiple check bin signals over the period of time are greater than the empty bin threshold signal. The emitter may be an infrared light emitter. In some examples, a diffuser positioned over the emitter to diffuse the emitted signal. In some implementations, the emitter is disposed on a first interior surface of the cleaning bin housing and the detector is disposed on an opposing, second interior surface of the cleaning bin housing.

The details of one or more implementations of the disclosure are set fourth in the accompanying drawings and the

description below. Other features, objects, and advantages will be apparent from the description and drawings, and from the claims.

DESCRIPTION OF DRAWINGS

FIG. 1A is a top view of an autonomous robotic cleaner.

FIG. 1B is a bottom view of an autonomous robotic cleaner.

FIG. 1C is a side view of an autonomous robotic cleaner.

FIG. 2 is a block diagram of systems of an autonomous robotic cleaner.

FIGS. 3A-3B are top views of autonomous robotic cleaners.

FIG. 3C is a rear perspective view of an autonomous robotic cleaner.

FIGS. 3D-3E are bottom views of autonomous robotic cleaners.

FIGS. 3F-3G are perspective views of an autonomous robotic cleaner.

FIGS. 4A-4B are perspective views of removable cleaning bins.

FIGS. 4C-4E are schematic views an autonomous robotic cleaner.

FIG. 5A is a top view of an autonomous robotic cleaner.

FIG. 5B is a top view of a bin sensor brush.

FIGS. 6A-6C are schematic views of autonomous robotic cleaners.

FIGS. 7A-7B are front views of removable cleaning bins.

FIGS. 7C-7E are perspective views of removable cleaning bins.

FIGS. 7F-7H are front views of removable cleaning bins.

FIGS. 8A-8E are schematic views of removable cleaning bins.

FIG. 9A is a bottom view of an autonomous robotic cleaner.

FIG. 9B is a perspective view of a robot locking device.

FIGS. 10A-10B are schematic views of autonomous robotic cleaners.

FIG. 11A is a perspective view of a cleaning bin.

FIGS. 11B-11D are schematic views of cleaning bin indicators.

FIG. 12A is a schematic view of a cleaning bin indicator system.

FIGS. 12B-12C are schematic views of remote cleaning bin indicators.

FIG. 12D is a schematic view of an autonomous robotic cleaner and an evacuation station.

FIGS. 13-32 are process flow charts of bin-fullness detection systems.

Like reference symbols in the various drawings indicate like elements.

DETAILED DESCRIPTION

Referring to FIGS. 1A-1D, an autonomous robotic cleaner 11 includes a chassis 31 which carries an outer shell 6. FIG. 1A illustrates the outer shell 6 of the robot 11 connected to a bumper 5. An omnidirectional receiver 15 and a control panel 10 are both carried by the outer shell 6. The omnidirectional receiver 15 has a 360 degree line of vision that allowing detection of signals emitted towards the robot 11 from substantially all directions.

Referring to FIG. 1B, the robot 11 may move in forward and reverse drive directions; consequently, the chassis 31 has corresponding forward and back ends, 31A and 31B respectively. Infrared light (IR) cliff sensors 30 are installed on the underside of the robot 11 proximate the forward end 31A of

the chassis 31. The cliff sensors 30 are configured to detect sudden changes in floor characteristics indicative of an edge or cliff of the floor (e.g. an edge of a stair). The forward end 31A of the chassis 31 includes a caster wheel 35 which provides additional support for the robot 11 as a third point of contact with the floor and does not hinder robot mobility. Located proximate to and on either side of the caster wheel 35 are two wheel-floor proximity sensors 70. The wheel-floor proximity sensors 70 are configured to detect sudden changes in floor characteristics indicative of an edge or cliff of the floor (e.g. an edge of a stair). The wheel-floor proximity sensors 70 provide redundancy should the primary cliff sensors 30 fail to detect an edge or cliff. In some implementations, the wheel-floor proximity sensors 70 are not included, while the primary cliff sensors 31 remain installed along the bottom front edge of the chassis 31. A lock assembly 72 on a bottom side of robot chassis 31 is configured to engage a corresponding lock assembly installed on a maintenance station for securing the robot 11 during servicing.

A cleaning head assembly 40 is located towards the middle of the robot 11 and installed within the chassis 31. The cleaning head assembly 40 includes a main 65 brush and a secondary brush 60. A battery 25 is housed within the chassis 31 proximate the cleaning head assembly 40. In some examples, the main 65 and/or the secondary brush 60 are removable. In other examples, the cleaning head assembly 40 includes a fixed main brush 65 and/or secondary brush 60, where fixed refers to a brush permanently installed on the chassis 31.

Installed along either side of the chassis 31 are differentially driven wheels 45 that mobilize the robot 11 and provide two points of support. Also installed along the side of the chassis 31 is a side brush 20 configured to rotate 360 degrees when the robot 11 is operational. The rotation of the side brush 20 allows the robot 11 to better clean areas adjacent the robot's side, and areas otherwise unreachable by the centrally located cleaning head assembly 40.

A removable cleaning bin 50 is located towards the back end 31B of the robot 11 and installed within the outer shell 6. The cleaning bin 50 is removable from the chassis 31 to provide access to bin contents and an internal filter 54. Additional access to the cleaning bin 50 may be provided via an evacuation port 80, as shown in FIG. 1C. In some implementations, the evacuation port 80 includes a set of sliding side panels 55 which slide along a side wall of the chassis 31 and under side panels of the outer shell 6 to open the evacuation port 80. The evacuation port 80 is configured to mate with corresponding evacuation ports on a maintenance station 1250. In other implementations, the evacuation port 80 is installed along an edge of the outer shell 6, on a top most portion of the outer shell 6, on the bottom of the chassis 31, or other similar placements where the evacuation port 80 has ready access to the contents of the cleaning bin 50.

In some implementations, the robot 11 includes a communication module 90 installed on the bottom of the chassis 31. The communication module 90 provides a communication link between a maintenance station 1250 and the robot 11. The communication module 90, in some instances, includes both an emitter and a detector, and provides an alternative communication path while the robot 11 is located within the maintenance station 1250. In some implementations, the robot 11 includes a brush service sensor assembly 85 installed on either side of and proximate the cleaning head 40. The brush service sensor assembly 85 provides user and system feedback regarding a degree of filament wound about the main brush 65, the secondary brush 60, or both. The brush service sensor assembly 85 includes an emitter 85A for emitting modulated beams and a detector 85B configured to detect

the beams. The emitter **85**A and the detector **86**B are positioned on opposite sides of the cleaning head **60**, **65** and aligned to detect filament wound about the cleaning head **60**, **65**. The brush service sensor assembly **85** includes a signal processing circuit configured to receive and interpret detector output. The emitter **85**A is aligned along a rotating axis of the bush **60**, **65** and between rows of bristles (or flaps) so that when no errant filaments are present on the bush **60**, **65**, a signal transmission between the emitter **85**A and the detector **86**B is not blocked. A presence of a few errant filaments spooled about the bush **60**, **65** partially blocks a signal transmission between the emitter **85**A and the detector **86**B. When accumulation of errant filaments wrapped about the brush **60**, **65** circumferentially and longitudinally reaches a certain threshold, a signal transmission between the emitter **85**A and the detector **86**B is substantially blocked by a corresponding threshold amount. Accumulation of errant filaments across the whole brush or locally in a ring clump are both detected at an appropriate time for maintenance.

FIG. **2** is a block diagram of systems included within the robot **11**. The robot **11** includes a microprocessor **245** capable of executing routines and generating and sending control signals to actuators within the robot **200**. Connected to the microprocessor **245** is memory **225** for storing routines and sensor input and output, a power system **220** with a battery **25** and a plurality of amplifiers able to generate and distribute power to the microprocessor **245**, and other components included within the robot **11**. A data module **240** is connected to the microprocessor **245** which may include ROM, RAM, an EEPROM or Flash memory. The data module **240** may store values generated within the robot **11** or to upload new software routines or values to the robot **11**.

The microprocessor **245** is connected to a plurality of assemblies and systems, one of which is the communication system **205** including an RS-232 transceiver, radio, Ethernet, and wireless communicators. The drive assembly **210** is connected to the microprocessor **245** and includes right and left differentially driven wheels **45**, right and left wheel motors, and wheel encoders. The drive assembly **210** is operable to receive commands from the microprocessor **245** and generate sensor data transmitted back to the microprocessor **245** via the communication system **205**. A separate caster wheel assembly **230** is connected to the microprocessor **245** and includes a caster wheel **35** and a wheel encoder. The cleaning assembly **215** is connected to the microprocessor **245** and includes a primary brush **65**, a secondary brush **60**, a side brush **20**, and brush motors associated with each brush. Also connected to the microprocessor is the sensor assembly **235** which may include infrared proximity sensors **75**, an omnidirectional detector **15**, mechanical switches installed in the bumper **5**, wheel-floor proximity sensors **70**, stasis sensors, a gyroscope, and infrared cliff sensors **30**.

FIGS. **3**A-**3**E illustrate various example locations of disposing the cleaning bin **50** and a filter **54** on the chassis **31** and the outer shell **6**. FIG. **3**A displays a robot **300**A with an evacuation port **305** disposed on the top of the robot **300**A, and more specifically installed on the top of a cleaning bin **310**A. The cleaning bin **310**A may or may not be removable from the chassis **31** and outer shell **6**, and if removable, is removable such that the bin **310**A separates from a back potion **312**A of the robot **300**A.

Referring to FIG. **3**B, a cleaning bin **310**B is installed towards the rearward end of a robot **310**B and includes a latch **315**. A top **311** of the cleaning bin **310**B slides toward the forward end of the robot **310**B when the latch **315** is manipulated, so that contents of the cleaning bin **310**B can be removed. The outer shell **6** includes no latch for the removal

of the filter **54**. To access the filter **54**, the cleaning bin **310**B is removed from a back potion **312**B of the robot **310**B. In this implementation, the cleaning bin latch **315** may be manipulated manually by the operator or autonomously by a robotically driven manipulator.

FIG. **3**C illustrates a robot **300**C including a cleaning bin **310**C located on a rearmost side wall **320** of the outer shell **6**. The cleaning bin **310**C has a set of movable doors **350** that when actuated, slide along the side of the chassis **31** and under the outer shell **6**. Once the doors **350** recess under the outer shell **6**, the cleaning bin **310**C is then configured to accept and mate with an external evacuation port.

FIG. **3**D provides a bottom view of a robot **300**D and the bottom of the cleaning bin **310**D located on the bottom back end of the robot **300**D. The cleaning bin **310**D has a latch **370** allowing a door **365** located on the bottom of cleaning bin **310**D to slide towards the forward end of the robot **300**D so that contents of the cleaning bin **310**D may be removed. The filter **54** cannot be accessed from the outer shell **6**. The cleaning bin **310**D must be removed from a back portion **312**D of the robot **300**D to clean the filter **54**. The cleaning bin **310**D and latch **370** may be manipulated manually by an operator or autonomously by a robotically driven manipulator.

FIG. **3**E provides a bottom view of a robot **300**E and the floor of the cleaning bin **310**E located on the bottom, back end of the robot **300**E. The cleaning bin **310**E includes a port **380** for accessing contents of the cleaning bin **310**E. An evacuation hose may be attached to the port **380** to evacuate the cleaning bin **310**E. The cleaning bin **310**E must be removed from a back portion **312**E of the robot **300**D to access and clean the filter **54**.

Referring to FIG. **3**F, a robot **300**F includes a cleaning bin **310**F located on a rear robot portion **312**F. The cleaning bin **310**F includes two or more evacuation ports **380** on a rear side (three are shown). The evacuation ports **380** are configured to receive an evacuation hose for removing debris from the bin **310**F.

Referring to FIG. **3**G, a robot **300**G includes a cleaning bin **310**G located on a rear robot portion **312**G The cleaning bin **310**G includes one or more evacuation ports **380** on a side portion (e.g. left and/or right sides). The evacuation ports **380** are configured to receive an evacuation hose for removing debris from the bin **310**G.

The robotic cleaner **11** receives a number of different cleaning bins **50**. Referring to FIG. **4**A, a cleaning bin **400**A is configured to mate with external vacuum evacuation ports. The vacuum bin **400**A defines a main chamber **405**A having a sloped floor **410**A that aids movement of debris towards evacuation ports **415**, **420**, **425**. A first side evacuation port **415** is located adjacent a center evacuation port **420** which is located between the first side evacuation port **415** and a second side evacuation port **425**. Located on the side walls of the bin **400**A are two evacuation outlets **430** that are installed to further aid a vacuum in its evacuation operation.

Referring to FIG. **4**B, a bin **400**B includes teeth **450** along a mouth edge **452** of the bin **400**B. The teeth **450** reduce the amount of filament build up on the main brush **60** and/or the secondary brush **65** by placing the bin **400**B close enough to the brush **60**, **65** such that the teeth **492** slide under filament on the brush **60**, **65** and pull off filament as the brush **60**, **65** rotates. In some examples, the bin **400**B includes between about 24-36 teeth. In the example shown, the bin **400**B defines a sweeper bin portion **460** and a vacuum bin portion **465**. The comb or teeth **450** are positioned between the sweeper bin portion **460** and the vacuum bin portion **465** and presented to lightly comb the sweeper brush **60**. The comb or teeth **450** remove errant filaments from the sweeper brush **60**

that accumulate either on the teeth 450 or in the sweeper bin portion 460. The vacuum bin portion 465 and the teeth 450 above it do not interfere with each other. The bin 400B carries a vacuum assembly 480 (e.g. a vacuum motor/fan) configured to draw debris past a pair of squeegees 470A and 470B in the vacuum bin portion 460. Electrical contacts 482A, 482B provide power to the vacuum assembly 480. In some examples, the electrical contacts 482A, 482B provide communication to a bin microprocessor 217. A filter 54 separates the vacuum bin portion 460 from the vacuum assembly 480. In some examples, the filter 54 pivots open along a side, top, or bottom edge for servicing. In other examples, the filter 54 slides out of the vacuum bin portion 460.

Referring to FIG. 4C, a bin 400C defines a sweeper bin portion 460 and a dispenser portion 466. The sweeper bin portion 460 is configured to receive debris agitated by the brush 60 and the flapper roller 65. The brush 60 and the flapper roller 65 may rotate in the same direction or opposite directions. The bin 400C includes driven vanes 472 configured to churn a substance 474 (e.g. powdered freshener) for dispersion. In some examples, a dispersion cam 476 (e.g. a single row of teeth on a rotatable shaft or roller) opens a spring biased flap 477 allowing the churned freshener to be disposed. In other examples, the dispersion cam 476 rotated among open and closed positions to control freshener dispersion. In some examples, the bin 400C includes teeth 450 disposed along a sweeper bin portion opening are configured to engage the brush 60 to remove filament and debris from the brush.

Referring to FIG. 4D, a bin 400D defines a sweeper bin portion 460 and a dispenser portion 467. The bin 400D includes a sprayer 473 configured to spray a substance 474 (e.g. liquid or powder freshener) when actuated by a dispersion cam 476. In some examples, the dispersion cam 476 rotates a spring biased flap 477 that actuates the sprayer 473.

Referring to FIG. 4E, a bin 400E defines a sweeper bin portion 460 which includes at least one chased plate 468 configured to attract particulate or debris. In some examples, the bin 400E defines a dispenser portion 466 including driven vanes 472 configured to churn a substance 474 (e.g. powdered freshener) for dispersion. Air may be forced through dispenser portion 466 (e.g. via a fan) to treat the air.

Referring to FIGS. 5A-5B, in some instances, the bin 50 includes a bin-full detection system 700 for sensing an amount of debris present in the bin 50. In one implementation, the bin-full detection system includes an emitter 755 and a detector 760 housed in the bin 50. A housing 757 surrounds each the emitter 755 and the detector 760 and is substantially free from debris when the bin 50 is also free of debris. In one implementation, the bin 50 is detachably connected to the robotic cleaner 11 and includes a brush assembly 770 for removing debris and soot from the surface of the emitter/detector housing 757. The brush assembly 770 includes a brush 772 mounted on the chassis 31 and configured to sweep against the emitter/detector housing 757 when the bin 50 is removed from or attached to the robot 11. The brush 772 includes a cleaning head 774 (e.g. bristles or sponge) at a distal end farthest from the robot 11 and a window section 776 positioned toward a base of the brush 772 and aligned with the emitter 755 or detector 760 when the bin 50 is attached to the robot 11. The emitter 755 transmits and the detector 760 receives light through the window 776. In addition to brushing debris away from the emitter 755 and detector 760, the cleaning head 774 prevents debris or dust from reaching the emitter 755 and detector 760 when the bin 50 is attached to the robot 11. In some examples, the window 776 comprises a transparent or translucent material and formed integrally with

the cleaning head 774. In some examples, the emitter 755 and the detector 760 are mounted on the chassis 31 of the robot 11 and the cleaning head 774 and/or window 776 are mounted on the bin 50.

FIG. 6A illustrates a sweeper robot 11 including a brush 60 and a flap 65 that sweep debris into a bin 700A having an emitter 755 and a detector 760 both positioned near a bin mouth 701. FIG. 6B illustrates an implementation in which a bin 700B includes a vacuum/blower motor 780, and an emitter 755 and a detector 760 located near an inlet 782 of a vacuum flow path into the bin 700B. The chassis 31 of the robot 11 includes a robot vacuum outlet 784 that fits flush with the vacuum inlet 782 of the bin 700B. By placing the emitter 755 and the detector 760 near the debris inlet 782, the debris is measured along the intake flow path rather than within the debris chamber 785. Therefore, a bin-full condition is triggered when either the amount of debris swept or vacuumed along the flow path is extremely high (which may typically be a rare scenario), or when the debris chamber 785 is full (e.g. debris is no longer deposited therein, but instead backs up along the intake flow path near the inlet 782).

FIG. 6C illustrates a combined vacuum/sweeper bin 700C including an emitter 755 and a detector 760 pair positioned near a sweeper bin inlet 782A and a vacuum bin inlet 782B. An emitter 755 and a detector 760 are mounted on the chassis 31 of the robot 11 near the bin inlet 782. Alternatively to or in combination with the inlet sensors 755, 760, several emitter arrays 788 are positioned on a bottom interior surface of the bin 700C and one more detectors 760 are positioned on a top interior surface of the bin 700C. Signals from the detectors 760 located along the intake flow path, as well as the container of the bin 700C, may be compared for determining bin fullness. For example, when a heavy volume of debris is pulled into the bin 700C by the brush 60, flapper 65, and/or vacuum motor 780, the detectors 760 located along the flow path may generate a low detection signal. However, detectors 760 located on the top interior surface of the bin 700D will not detect a full bin 700C, if it is not yet full. Comparison of the detector signals avoids a false bin-full condition.

FIGS. 7A-7E illustrate a transmissive optical debris-sensing system for detecting debris within the bin 50. As shown in FIG. 7A, in some examples, the bin 50 includes emitters 755 located on a bottom interior surface 51 of the bin 50 and detectors 760 located on an upper interior surface 52 of the bin 50. The emitters 755 emit light that traverses the interior of the bin 50 and which may be detected by the detectors 760. When the interior of the bin 50 is clear of debris, the transmitted light from the emitters 755 produces a relatively high signal strength in the detectors 760, because very little of the transmitted light is diverted or deflected away from the detectors 760 as the transmitted light passes through the empty interior of the bin 50. By contrast, when the interior of the bin 50 contains debris, at least some of the light transmitted from the emitters 755 is absorbed, reflected, or diverted as the light strikes the debris, such that a lower proportion of the emitted light reaches the detectors 760. The degree of diversion or deflection caused by the debris in the interior of the bin 50 correlates positively with the amount of debris within the bin 50.

By comparing the signals generated by the detectors 760 when the bin 50 does not contain debris to subsequent signal readings obtained by the detectors 760 as the robot 11 sweeps and vacuums debris into the bin 50 during a cleaning cycle, the presence of debris within the bin 50 may be determined. For example, when the subsequently polled detector signals are compared to initial detector signals (taken when the bin 50

is empty), a determination can be made whether the debris accumulated within the bin **50** has reached a level sufficient to trigger a bin-full condition.

One example bin configuration includes one emitter **755** and two detectors **760**. Another configuration includes positioning one or more emitters **755** and detectors **760** in cross-directed in mutually orthogonal directions. The robot **11** may determine that heavy debris has accumulated on the bottom of the bin **50** but has not filled the bin **50**, when signals generated by a first detector **760** on the inner top surface **52** is relatively low and signals generated by a second detector **760** on an inner side wall (which detects horizontally-transmitted light) does not meet a bin-full threshold. On the other hand, when both detectors **760** report a relatively low received-light signal, it may be determined that the bin **50** is full.

FIG. 7B illustrates a bin configuration in which the bin **50** includes a detector **760** located proximate a calibration emitter **805**, both disposed behind a shield **801** on the top interior surface **52** of the bin **50**. An emitter **755** is disposed on the bottom interior surface **51** of the bin **50**. A calibration signal reading is obtained by emitting light from the calibration emitter **805** which is then detected by the detector **760** as a first reading. The translucent or transparent shield **801** prevents emission interfere between the transmission of light from the calibration emitter **805** to the detector **760** with dust or debris from the bin **50**. The emitter **755** then transmits light across the interior of the bin **50** and the detector **760** takes a second reading of received light. By comparing the second reading to the first reading, a determination may be made whether the bin **50** is full of debris. In some examples, the robot **11** includes sensors **755**, **760** positioned along a debris flow path prior to a mouth **53** of the bin **50**. The bin full sensors **755**, **760** may detect debris tending to escape from the bin **50**.

FIG. 7C illustrates a configuration in which the bin **50** includes two emitter arrays **788** and two detectors **760**. Each emitter array **788** may include several light sources. The light sources may each emit light frequencies that differ from one another within the same emitter arrays **788**. For example, varying frequencies of light emitted by the light sources exhibit various levels of absorption by debris of different sizes. A first sub-emitter within the emitter array **788** may emit light at a first frequency, which is absorbed by debris of very small particle size, while a second sub-emitter within the emitter arrays **788** may emit light at a second frequency which is not absorbed by small-sized debris particles. The robot **11** may be determine whether the bin **50** is full even when the particle size of the debris varies by measuring and comparing the received light signals from the first and second sub-emitters. Undesirable interference with the optical transmissive detection system may be avoided by employing sub-emitters emitting light at different frequencies.

Multiple emitter arrays **788** and detectors **760** provide more accurate and reliable bin fullness detection. In the example shown, the multiple emitter arrays **788** provide cross-bin signals to detect potential bin blockages. One possible blockage location is near an intruding vacuum holding bulkhead **59**, which partially divides the bin **50** into two lateral compartments. This does not apply to all bins **50**. A blockage may occur when received artifact debris of a large enough size (e.g. paper or hairball) becomes a blocking and compartmentalizing bulkhead in the bin **50**. A blockage may occur when shifting, clumping, moving, vibrated, or pushed debris within the bin creates one or more compartments via systematic patterns of accumulation. If debris accumulates in one lateral compartment, but not another, a single detector pair may miss it. A single detector pair may also provide a

false-positive signal from a large debris item or clump. Multiple emitter arrays **788** located on the bottom interior surface **51** of the bin **50** and multiple detectors **760** located on the top interior surface **52** of the bin **50** in two different lateral or front-to-back locations covers more potential volume of the bin **50** for more accurate and reliable bin fullness detection. A histogram or averaging of the bin detector signals or using XOR or AND on the results of more than one break-beam may be used to get more true positives (even depending on the time since accumulation began).

FIG. 7D illustrates a bin **50** with a transmissive optical detection system including two emitter arrays **788**, each having a diffuser **790** diffusing emitted infrared light. The diffuse light transmitted to the interior of the bin **50** provides a steadier detection signal generated by the detectors **760** relative to a detection signal generated from a concentrated beam of light from a non-diffuse light source. The diffuse light provides a type of physical averaging of the emitted signal. The detectors **760** receiving diffused infrared light signals can measure an overall blockage amount versus interruption of only a line-of-sight break beam from one emitter.

FIG. 7E illustrates a bin **50** including a light pipe or fiber-optic pathway **792** disposed on the bottom interior surface **51** of the bin **50**. Light from a light source **793** in the bin **50** travels along the fiber-optic pathway **792** and is emitted from distributor terminals **794**. This bin configuration centralizes light production to the single light source **793**, rather than supplying power to several independent light sources, while distributes light across the bin **50**. The distributor terminals **794** may also include a diffuser **790**, as discussed above.

FIGS. 7F-7H illustrate optical debris detection in the bin **50** by reflective light transmission. In one example, as illustrated in FIG. 7F, the bin **50** includes a shielded emitter **756** located near a detector **760**. Light emitted by the shielded emitter **756** does not travel directly to the detector **760** because of the shielding. However, light emitted from the emitter **756** is reflected by the interior surface **55** of the bin **50**, and traverses an indirect path to the detectors **760**. The attenuation of the reflected light caused by debris within the bin **50** may be comparatively greater than in a direct transmissive configuration, because the path the reflected light must travel within the bin **50** is effectively doubled, for example. Although the shielded emitter **756** and detector **760** are illustrated as being proximal to each other, they may be located distally from each other. The emitter **756** and detector **760** may be positioned on the same surface, or on different surfaces.

FIG. 7G illustrates two sets of shielded emitters **756** and detectors **760**, each located on opposite horizontal sides of the interior of the bin **50**. In this configuration, light received by each detector **760** may be a combination of light directly transmitted from the shielded emitter **756** located on the opposite side of the bin **50**, as well as light reflected off the interior surface **55** by the proximal shielded emitter **756**. In some examples, a first set of shielded emitters **756** and detectors **760** is located on an adjacent bin surface from a second set of shielded emitters **756** and detectors **760**. In one example, a single shielded emitter **756** and detector **760** pair is located on a bottom surface **51** of the bin **50**.

FIG. 7H illustrates a configuration in which the bin **50** includes a diffusive screen **412** placed along the transmission path of the shielded emitter **756** disposed on a bottom surface **51** of the bin **50**. The diffusive screen **790** diffuses light emitted from the shielded emitter **756** that reflects off various surfaces of the interior **55** of the bin **50** before reaching the detector **760**, thereby providing a detection signal that reflects a broad area of the interior of the bin **50**.

The robot **11**, in some implementations, measures or detects air flow to determine the presence of debris within the bin **50**. FIGS. **8A-8B** illustrate an air flow detection system **800** for detecting a bin-full state. The bin **50** includes an air flow detector **810**. As illustrated in FIG. **8A**, when high air flow is detected by the air flow detector **810**, the bin **50** determines that the interior is not full, because a high level of debris would obstruct air flow within the bin **50**. Conversely, as illustrated in FIG. **8B**, when the bin **50** contains a large quantity of debris, the air flow within the bin **50** stagnates. Therefore, air flow detected by the air flow detector **810** declines and the bin **50** determines that the debris level is full.

In some example, the bin **50** includes a rotating member **812** which influences an air volume to flow within the bin **50**, guided by the inner surface **55** of the bin **50**. The rotating member **812** may be disposed inside or outside of the bin **50** (anchored or free, e.g, a wire, a vane, a brush, a blade, a beam, a membrane, a fork, a flap). In some instances, the rotating member **812** is an existing fan or blower from which air is diverted. In other instances, the rotating member **812** includes a brush or paddle having a primary purpose of moving debris or particulates. The rotating member **812** may be diverted from a wheel chamber or other moving member chamber. "Rotation" and "rotating" as used herein, for sensors and/or cleaning members, includes transformations of rotation into linear motion, and thereby expressly includes reciprocating and sweeping movements. The air flow sensor **810** is disposed in the air volume that generates a signal corresponding to a change in an air flow characteristic within the bin **50** in response to a presence of material collected in the bin **50**.

In some implementations, the air flow sensor **810** includes a thermal sensor **862**, such as a thermistor, thermocouple, bimetallic element, IR photo-element, or the like. The thermal sensor **862** may have a long or short time constant, and can be arranged to measure static temperature, temperature change, rate of temperature change, or transient characteristics or spikes. The thermal sensor **862** may be passive, active, or excited. An example of a thermal sensor **862** that is excited is a self-heating thermistor, which is cyclically excited for a fixed time at a fixed voltage, in which the cooling behavior of the thermistor is responsive to air flow over the thermistor. Different thermistors and thermistor packaging may be used, e.g. beads or glass packages, having different nominal resistances and negative temperature coefficient of resistance vs. positive temperature coefficient of resistance.

FIG. **8C** illustrates a temperature sensing systems for detecting a bin-full state. In some examples, the bin **50** includes a self-heating thermistor **862** placed along an air flow path **864** from an air duct **865** of the bin **50**. Air flow is generated by suction of a vacuum motor **880**, for example. The thermistor **862** is heated to a predetermined temperature (e.g. by applying an electric current to a heating coil surrounding the thermistor **864**). A predetermined period of time is permitted to elapse without applying further heating to the thermistor **862** before reading the thermistor temperature of the **862**. When air flow within the bin **50** is relatively high, the temperature detected by the thermistor **862** is relatively low because the circulating air cools the thermistor **862**. Conversely, when the air flow is stagnant, the temperature detected by the thermistor **862** is relatively high, because of less cooling of the thermistor **862**. The robot **11** determines whether the bin **50** is full or not based on the relative temperature detected by the thermistor **862** following the heating and cooling-off cycle. Accuracy can be achieved by disposing two thermistors **862** in appropriate positions in the bin **50**. A first thermistors **862** measures ambient temperature, and a second thermistors **862** to heat above the ambient tempera-

ture. Air flow generally dissipates heat generated by the thermistor **862**. A lack of air flow typically relates to generally higher temperatures. Long thermal time constants associated with the temperature differences tend to result in good noise resistance and benefit from a built-in running averages effect, aggregating previous measurements automatically to produce a more accurate determination.

Placing the thermistor **862** in a location of the bin **50** empirically determined to have more or less air flow in general, it is possible to tune the sensitivity of air flow inference by the thermistors **862**. The thermistor **862** may be shielded or define holes to obtain better air flow over the thermistor, enhancing thermistor sensitivity. The fluid dynamics of a bin **50** actively filling with randomly shaped debris and randomly perturbed air flow is inherently predictable, and routine experimentation is necessary to determine the best location for any sensors mentioned herein.

By adopting a total heating/cooling cycle time of about one minute (30 seconds heating, 30 seconds cooling, although this could be varied by an order of magnitude), the long thermal time constant of the system may prevent the thermistor **862** from responding too quickly. Air flow may also affect the time constant and the peak-to-peak change in temperature during cycling as well as reducing the long-term average temperature over many cycles.

Convection may be used if heating occurs at the bottom and temperature sensing at the top of the thermistor **862**. Convection be used in the vacuum bin **50** to sense a clogged filter (usually equivalent to a full bin for the vacuum chamber, which tends to collect microscopic material only). Air flow decreases when the filter **54** is clogged. If the air flow decreases, a higher temperature change is produced. Alternatively, the slope of the heating/cooling cycle, averaged, may also be used to detect filter clogging and/or blocked air flow.

FIG. **8D** illustrates a pressure sensing systems for detecting a bin-full state. In some implementations, the air flow sensor **810** includes a pressure transducer **863**, which may have a long or short time constant. The pressure transducer **863** may be arranged to measure static pressure (e.g., strain gauge pressure transducer), overpressure, back pressure, pressure change, rate of pressure change, or transient characteristics or spikes (e.g., piezo pressure transducer). The pressure transducer **863** can be passive, active, or excited, and can be arranged to measure air flow directly or indirectly by Bernoulli/venturi principles (in which more flow past a venturi tube creates lower pressure, which can be measured transiently or on an averaged basis to infer low air flow and a full bin when a low pressure zone is not detected).

A relatively small air pathway **868** (herein a "Venturi tube") extends orthogonally from the interior surface **55** of the bin **50**. The robot **11** determines bin fullness based on the relative pressure detected by the pressure transducer **863** at a distal end **869** of the Venturi tube **868**. When air flow along the interior surface of the bin **50** is high, the pressure at the distal end **869** of the Venturi tube **868** is relatively low. The pressure readings may be combined with thermistor and/or optical sensor readings to more accurately determine the presence of debris, for example.

Referring to FIG. **8E**, in some implementations, the bin **50** includes a vibration, resonance, or acoustic sensor **892** and an agitator or sonic emitter **894** configured to acoustically stimulate or perturb the bin **50**, the air within the bin **50**, or a sensing element provided in the bin **50** (e.g., with a known value or values for the vibrational response of an empty bin, so as to permit LaPlace-domain or other frequency, spectra, or response function oriented analyses). The agitator **894** acoustically stimulates the bin at least two different frequencies

(including pings, discrete frequencies or a continuous sweep), e.g., which can serve to compensate for loads of varying consistency, density or other potentially confounding factors. The robot **11** includes an analyzer **896** configured to analyze vibration or resonance data detected by the vibration or resonance sensor **892** in response to the acoustical stimulation of the bin **50** by the agitator or sonic emitter **894** and to indicate when the bin **50** is full to capacity.

In some examples, at various periods the agitator **894**, under the control of the analyzer circuit **896**, perturbs the air remaining within the bin **50** with a known vibration strength. At the same time, the vibration sensor **892** measures a vibration response of the air in the bin **50** and transmits the measured values to the analyzer circuit **896**. With respective known empty and full characteristic vibration responses of the bin **50**, the analyzer circuit **896** analyzes the response from the vibration sensor **892** using methods such as frequency-domain transforms and comparisons (e.g., LaPlace or Fourier transforms, etc.) and returns an appropriate bin state.

When an acoustic signal is emitted from an acoustic emitter **894** at time T1, the transmitted signal initially traverses the interior of the bin **50** from the acoustic emitter **894** to an acoustic detector **892** located horizontally opposite the acoustic emitter **894**. At time T2, the signal is detected by the transmissive acoustic detector **892A**, after one time period $\tau 1$ has elapsed. The acoustic signal also reflects off the interior surface **55** of the bin **50** and re-traverses the interior of the bin **50** until it is received by the reflective acoustic detector **892B** at time T3, following another time period equal to $\tau 1$. When the detectors **892A** and **892B** are of similar sensitivity, the signal detected at time T3 is lower than the signal detected at time T2 (the difference in amplitude between the signal detected at T2 and the signal detected at T3 is referred to as $\Delta 1$).

A similar signal analysis is performed when the interior the bin **50** is full of debris. The signals received by the detectors **892A** and **892B** at times T2 and T3, respectively, may decline monotonically with respect to the initial signal emitted from emitter **894** at time T1. However, the amplitude difference between the signals detected at T2 and T3, designated $\Delta 2$, is greater than a corresponding amplitude difference $\Delta 1$. A time-of-flight that elapses as the acoustic signal traverses the interior of the bin **50** (herein referred to as $\tau 2$) is also greater than the time period $\tau 1$ corresponding to the bin-empty state. The bin-full state can be determined using a signal analysis when a signal emitted from the acoustic emitter **894** and detected by the transmissive acoustic detector **892A** and the reflective acoustic detector **892B** is compared to a bin empty condition (which may be initially recorded as a reference level when the bin is known to be empty, for example).

Any of these fore-mentioned methods for detecting, measuring, inferring or quantifying air flow and/or bin capacity may also be combined in any suitable permutation thereof, to further enhance the accuracy of bin capacity measuring results; in particular, for example, at least two differing bin capacity-measuring techniques may be employed such that if there is a weakness in one of the techniques—for example, where air flow may be halted due to a factor other than bin fullness, a straight pressure transducer might still produce accurate measurements of bin capacity, etc.

Referring to FIGS. **9A-B**, in some implementations, a clip catch **902** is installed on the bottom of the robot chassis **31** and configured to mate with a clip **904** on a maintenance station **1250**. The clip **904** engages the catch **902** to lock the robot **11** in place during servicing of the bin **50** and/or brushes or rollers **60**, **65**.

Existing robots **11** which do not include bin-sensing features may be retrofitted with a bin **50** including a bin-full sensor system **700**. Signals generated by the bin-full sensor system **700** are transmitted to the robot microprocessor **245** (e.g. via snap-in wires, a serial line, or a card edge for interfacing a bus controlled by a microcontroller; using wireless transmission, etc.). Alternatively, an existing actuator (e.g. a fan) monitored by the home robot is "hijacked" (i.e., a property of it is modified for new use). For example, when the bin **50** is full, a cleaning assembly microprocessor **215** energizes the fan motor in a pattern (e.g., three times in a row with predetermined timing). The retrofitted and firmware-updated robot processor **245** detects the distinctive current pattern on the fan and communicates to a user that the bin **50** is full. In another example, an existing sensor is "hijacked." For example, an IR emitter disposed on top of the bin **50** in a visible range of an omnidirectional virtual wall/docking sensor. A distinctive modulated IR chirp or pulse train emitted by the retrofitted bin **50** indicates that the bin **50** is full without overwhelming the virtual wall sensor. In yet another example, communications are made just to the user but not to any automated system. For example, a flashing light on the bin **50**, or a klaxon or other audio signaler, notifies the user that the bin **50** is full. Such retrofitting is not necessarily limited to the bin-capacity-sensing function, but may be extended to any suitable features amenable to similar retrofitting.

Using a manufacturer's server, a robot user may create a website containing information regarding his or her customized (or standard) robot **11** and share the information with other robot users. The server can also receive information from robots **11** pertaining to battery usage, bin fullness, scheduled cleaning times, required maintenance, cleaning patterns, room-size estimates, etc. Such information may be stored on the server and sent (e.g. with other information) to the user via e-mail from the manufacturer's server, for example.

Referring to FIGS. **10A-10B**, in some implementations, the robot **11** includes robot communication terminals **1012** and the bin **50** includes bin communication terminals **1014**. When the bin **50** is attached to the robot **11**, the bin communication terminals **1014** contact the corresponding robot communication terminals **1012**. Information regarding bin-full status is communicated from the bin **50** to the robot **11** via the communication terminals **1012**, **1014**, for example. In some examples, the robot **11** includes a demodulator/decoder **29** through which power is routed from the battery **25** through via the communication terminals **1012**, **1014** and to the bin **50**. Bin power/communication lines **1018** supply power to a vacuum motor **780** and to a bin microcontroller **217**. The bin microcontroller **217** monitors the bin-full status reported by the debris detection system **700** in the bin **50**, and piggybacks a reporting signal onto the power being transmitted over the bin-side lines **1018**. The piggybacked reporting signal is then transmitted to the demodulator/decoder **29** of the robot **11**. The microprocessor **245** of the robot **11** processes the bin full indication from the reporting signal piggybacked onto the power lines **1018**, for example. In some examples, the communication terminals **1012**, **1014** include serial ports operating in accordance with an appropriate serial communication standard (e.g. RS-232, USB, or a proprietary protocol). The bin microcontroller **217** monitors the bin-full status reported by the debris detection system **700** in the bin **50** independent of a robot controller, allowing the bin **50** to be used on robots without a debris detection system **700**. A robot software update may be required for the bin upgrade.

Referring to FIG. **10B**, in some implementations, the robot **11** includes an infrared light (IR) receiver **1020** and the bin **50**

includes a corresponding IR emitter **1022**. The IR emitter **1022** and IR receiver **1020** are positioned on the bin **50** and robot **11**, respectively, such that an IR signal transmitted from the IR emitter **1022** reaches the IR receiver **1020** when the bin **50** is attached to the robot **11**. In some examples, the IR emitter **1022** and the IR receiver **1020** both functions as emitters and receivers, allowing signals to be sent from the robot **11** to the bin **50**. In some examples, the robot **11** includes an omni-directional receiver **13** on the chassis **31** and configured to interact with a remote virtual wall beacon **1050** that emits and receives infrared signals. A signal from the IR emitter **1022** on the bin **50** is receivable by the omni-directional receiver **13** and/or the remote virtual wall beacon **1050** to communicate a bin fullness signal. If the robot **10** was retrofitted with the bin **50** to and received appropriate software, the retrofitted bin **50** can order the robot **10** to return to a maintenance station for servicing when the bin so is full.

FIGS. **11A-11D** illustrate a bin **50** including a bin-full indicator **1130**. In some examples the bin-full indicator **1130** includes visual indicator **1132** such as an LED (FIG. **11B**), LCD, a light bulb, a rotating message wheel (FIG. **11C**) or a rotating color wheel, or any other suitable visual indicator. The visual indicator **1132** may steadily emit light, flash, pulse, cycle through various colors, or advance through a color spectrum in order to indicate to the user that the bin **50** is full of debris, inter alia. The indicator **30** may include an analog display for indicating the relative degree of fullness of the bin **50**. For example, the bin **50** includes a translucent window over top of a rotatable color wheel. The translucent window permits the user to view a subsection of the color wheel rotated in accordance with a degree of fullness detected in the bin **50**, for example, from green (empty) to red (full). In some examples, the indicator **30** includes two or more LEDs which light up in numbers proportional to bin fullness, e.g., in a bar pattern. Alternatively, the indicator **1030** may be an electrical and/or mechanical indicator, such as a flag, a pop up, or message strip, for example. In other examples, the bin-full indicator **1130** includes an audible indicator **1134** such as a speaker, a beeper, a voice synthesizer, a bell, a piezo-speaker, or any other suitable device for audibly indicating bin-full status to the user. The audible indicator **1134** emits a sound such as a steady tone, a ring tone, a trill, a buzzing, an intermittent sound, or any other suitable audible indication. The audible indicator **1134** modulates the volume in order to draw attention to the bin-full status (for example, by repeatedly increasing and decreasing the volume). In some examples, as shown in FIG. **11D**, the indicator **1130** includes both visual and audible indicators, **1132** and **1134**, respectively. The user may turn off the visual indicator **1132** or audible indicator **1134** without emptying the bin **50**. In some implementations, the bin-full indicator **1130** is located on the chassis **31** or body **6** of the robot **11**.

Referring to FIGS. **12A-12B**, in some implementations, the bin **50** wirelessly transmits a signal to a remote indicator **1202** (via a transmitter **1201**, for example), which then indicates to a user that the bin is full using optical (e.g. LED, LCD, CRT, light bulb, etc.) and/or audio output (such as a speaker **1202C**). In one example, the remote indicator **1202** includes an electronic device mounted to a kitchen magnet. The remote indicator **1202** may provide (1) generalized robot maintenance notifications (2) a cleaning routine done notification (3) an abort and go home instruction, and (4) other control interaction with the robot **10** and/or bin **50**.

An existing robot **11**, which does not include any communication path or wiring for communicating with a bin-full sensor system **700** on the bin **50**, is nonetheless retrofitted with a bin **50** including a bin-full sensor system **700** and a

transmitter **1201**. "Retrofitting" generally means associating the bin with an existing, in-service robot, but for the purposes of this disclosure, at least additionally includes forward fitting, i.e., associating the bin with a newly produced robot in a compatible manner. Although the robot **11** cannot communicate with the bin-full sensor system **700** and may possibly not include any program or behavioral routines for responding to a bin-full condition, the bin **50** may nonetheless indicate to a user that the bin **50** is full by transmitting an appropriate signal via the transmitter **1201** to a remote indicator **1202**. The remote indicator **1202** may be located in a different room from the robot **11** and receives signals from the bin **50** wirelessly using any appropriate wireless communication method, such as IEEE 801.11/WiFi, BlueTooth, Zigbee, wireless USB, a frequency modulated signal, an amplitude modulated signal, or the like.

In some implementations, as shown in FIG. **12B**, the remote indicator **1202** is a magnet-mounted unit including an LED **1204** that lights up or flashes when the bin **50** is full. In some examples, as shown in FIG. **12C**, the remote indicator **1202** includes an LCD display **1206** for printing a message regarding the bin full condition and/or a speaker **1208** for emitting an audible signal to the user. The remote indicator **1202** may include a function button **1210**, which transmits a command to the robot **11** when activated. In some examples, the remote indicator **1202** includes an acknowledge button **1212** that transmits an appropriate command signal to the mobile robot **20** when pushed. For example, when a bin-full signal is received, the LCD display **1206** may display a message indicating to the user that the bin is full. The user may then press the button **1212**, causing a command to be transmitted to the robot **11** that in turn causes the robot **11** to navigate to a particular location. The user may then remove and empty the bin **50**, for example.

In some examples, the remote indicator **1202** is a table-top device or a component of a computer system. The remote indicator **1202** may be provided with a mounting device such as a chain, a clip or magnet on a reverse side, permitting it to be kept in a kitchen, pendant, or on a belt. The transmitter **1201** may communicate using WiFi or other home radio frequency (RF) network to the remote indicator **1202** that is part of the computer system **1204**, which may in turn cause the computer system to display a window informing the user of the bin-full status.

Referring to FIG. **12D**, when the bin-full detection system **700** determines that the bin **50** is full and/or the roller full sensor assembly **85** determines that the cleaning head **40** is full, the robot **11**, in some examples, maneuver to a maintenance station **1250** for servicing. In some examples, the maintenance station **1250** automatically evacuates the bin **50** (e.g. via a vacuum tube connecting to an evacuation port **80**, **305**, **380**, **415**, **420**, **425**, **430** of the bin **50**). If the cleaning head **40** is full of filament, the robot **11** may automatically discharge the cleaning brush/flapper **60**, **65** for either automatic or manual cleaning. The brush/flapper **60**, **65** may be fed into the maintenance station **1250**, either manually or automatically, which strips filament and debris from the brush/flapper **60**, **65**.

FIGS. **13-32** illustrate methods for controlling the bin-full detection and user-notification systems of the robot **11**. Steps or routines illustrated with dashed lines are expressly optional or include optional sub-routines. In some cases, steps may be omitted depending upon whether the bin is powered by its own battery or by a discharging capacitor.

A normal operating routine begins, as illustrated in FIG. **13**, by activating transducers (e.g. bin detection system **700**) to detect a bin full condition. The core operating cycle of the

bin **50** takes place while the robot **11** is operating (e.g. cleaning), in order to detect a bin full condition. However, optional cycles check the status of the bin **50** and robot **11** when the robot **11** is not operating.

For example, the bin processor **217** may have an idle or low-power mode that is active when the robot **11** is not powered and/or the bin **50** is detached. FIGS. **14** and **15** illustrate parent procedures used to enter this mode. For example, the controller **217** may start an optional power detect routine at step S**14-2**. "Power detect" in this context is detecting whether or not the bin **50** is attached to the robot **11** and the robot **11** is operating (cleaning). If power is detected/available, the bin **50** enters the normal operating mode (described below). If no power is available, then the bin controller **217** executes a no-power routine, as illustrated in FIG. **15**.

In the no-power mode, the bin **50** may have set a flag specifying notification is to be activated. If this is the case, a low-power notification is preferable. An optional step S**15-2** would change the notification from a continuous to a more intermittent notification (rapid flashing to slower flashing, continuous on to flashing, i.e., from a higher power consumption notification to a lower power consumption notification). This is less important when the bin **50** does not rely on robot power to recharge its own power supply.

Another optional step in the no-power routine is a sleep/wake check, as shown in step S**15-3**. If the bin **50** maintains the intermittent or regular notification S**15-2** (i.e., each step in the no-power routine is independent and optional, and may or may not depend on the execution of preceding steps), the bin **50** may enter a sleep state after a certain number of no-power (robot off), no-change (bin not disconnected from robot, bin not moved, no change in bin sensor states) minutes (e.g., 5 mins to 1 hour) elapses. The bin may wake upon disconnection from the robot **11**, movement of the bin **50** or robot **11**, any relevant change in bin sensor states; and may re-activate or activate checking and wake-state activities.

Another optional step in the no-power routine is an emptied check S**15-4**, which checks whether conditions reflect that the bin **50** has been emptied (including changes in internal sensor state indicative of emptying, tilt sensing, assumptions made). A subsequent step upon detection of bin emptying directly or indirectly is the deactivation of the notification (step S**15-5**) and resetting or restarting the processes.

Referring again to FIG. **13**, if power is detected, i.e., if the bin is connected to the robot **11** and the robot **11** is operating, transducer(s) are started at step S**13-2**. "Transducers", in this context, describes various instruments and sensors as described herein that are used to directly or indirectly check whether the bin is full and/or not empty. This includes virtual transducers. Step S**13-2** initiates bin monitoring via the transducer(s) until monitoring is no longer necessary.

Once the transducers are active, a not empty check is executed at step S**13-3**. "Not empty", in this context, describes positive, negative, and inferred sensor interpretations that may directly or indirectly check whether the bin is full, empty, and/or not empty and/or not full. Steps S**13-2** and **13-3** starts, and continues, a not-empty check via the transducer(s) until the same is registered, and may constitute the only such check, i.e., confirmation or verification is optional.

Optionally, a not empty verify routine may be executed at step S**13-4**. "Verify", in this context, describes repeating or extending the checks performed in step S**13-3**, or a different kind of check upon a same or different kind of criteria. A preferred example of the step S**13-4** correlates verification with sufficient elapsed time under a positive not-empty condition. Optionally, step S**13-4** includes routines to reject false positives.

Once the not-empty or bin full state is detected and optionally checked as stable, in one direction or the other, the controller **217** may activate notification in step S**13-5**. The notification may be kept on for a certain time period, and/or may be kept on until the bin is detected as emptied at step S**13-6**. Notification is turned off at step S**13-7**. Thereafter, the process is restarted at S**13-8**.

Examples of start transducer routines are illustrated in FIGS. **16-20**. Each routine includes appropriate calibration/tare/zeroing steps.

FIG. **16** illustrates an example start transducer routine appropriate for a single or combined/averaged illuminated emitter and or detector array in the bin **50**, either of the reflective type or break-beam/transmissive type. A start illumination cycle routine is executed at step S**16-2**. Empty/off levels are sampled from bin detectors and averaged at step S**16-3**. A not empty check threshold is set at step S**16-4**, before the process is returned at step S**16-5**. As illustrated in FIG. **17**, a similar process is executed in start transducer example 2 routine, in which empty/off levels are sampled for a set of 1 to N transducers. Each emitter/detector pair or combination is accounted for in the calibration or normalizing of empty or off levels in step **17-3**. FIG. **32** contemplates the case in which the same sensors are checked for different orientations, or combinations, or cycled time-wise, e.g., emitter A**1** with detector B**1**, emitter A**1** with detector B**2**, emitter A**2** with detector B**1**. The start transducer example 2 routine is appropriate when the same sensors in the emitter and/or detector arrays can identify sensor failure, or debris jams or clumps in the bin **50**.

FIGS. **18-19** illustrate example start transducer routines, in which an excitation cycle is started at step S**18-2** or S**19-2**. These routines are appropriate for bin detection systems **700** including hot-wire anemometers or thermistors, vibration sensors, time-of-flight acoustic measurements, or transducers that generate a signal in which the empty or full state that has a relatively more complex characterization. Calibration at step S**18-3** or S**19-3** may require identifying an empty waveform, signal, or envelope characteristic representing a range, envelope, or signal shape of transducer detection values corresponding to an empty bin **50**. The characteristic envelope is a baseline for measurements in step S**18-4** or S**19-4**. An intervening optional step can model, fit, or transform the shape or envelope so that less data is necessary for storage or comparison purposes.

FIG. **20** illustrates an example start transducer routine appropriate for an arrangement in which transducers are not calibrated, and/or in which heuristics, filters, and/or other non-linear rules are used to identify the bin full state. The transducers may nonetheless be normalized or calibrated.

FIGS. **21-24** illustrate example not empty check routines. FIG. **21** provides an example not empty check routine appropriate for a single or combined/averaged illuminated emitter and or detector array in the bin **50**. Illumination received by the detector of the transducer is measured at step S**21-2**. The measured illumination is compared to a threshold illumination level corresponding to the bin empty state in step S**21-3**. If received illumination is below the threshold, the process loops back to step S**21-2**. Otherwise, the routine returns at step S**21-4**.

FIG. **22** provides a second example not empty check routine appropriate for a matrix of transducers. Illumination received by a set of 1 to N transducers is measured in step S**22-2**. The received illumination of the 1 to N transducers is compared to a set of 1 to N threshold levels is step S**22-3**. If

received illumination is below the threshold, the process loops back to step S22-2. Otherwise, the routine returns at step S22-4.

FIG. 23 illustrates a third example not empty check routine, in which characteristics of a received signal of a transducer are tested at step S23-2. A determination of whether the tested characteristic passes the not empty check is made at step S23-3. If the tested characteristic of the received signal passes, the routine returns at step S23-4; otherwise, the process repeats step S23-2.

FIG. 24 illustrates a fourth example not empty check routine, in which a signal received by a transducer is processed and tested as it is processed at step S24-2. If the ongoing testing of the signal passes at step S24-3, the routine returns at step S24-4; otherwise, the routine repeats step S24-2.

FIGS. 25-28 illustrate example not empty verification routines. FIG. 25 illustrates one example not empty verification routine including a start sustain timer (e.g., 5 mins) step S25-2. In step S25-3, it is determined whether a received signal of a transducer remains above a threshold level. The sustain timer sets the period for which the not-empty detection must continue in order to establish the stable bin full condition. If the received signal of the transducer continues to be above a threshold level at step S25-3, it is then determined whether the timer has elapsed at step S25-4. If the timer has elapsed, the stable bin full condition is established and the routine returns at step S25-5. If the timer has not yet elapsed, the routine loops back to step S25-3 to check whether received signals at the transducer remain above the threshold.

FIG. 26 illustrates a second example of a not empty verification routine, in which the received signals of a set of 1 . . . N transducers are compared to a set of 1 . . . N thresholds in step S26-3. If any sensor falls below the threshold, the sustain timer is restarted at step S26-2.

In a third example, illustrated in FIG. 27, when any transducer falls below the threshold level at step 27-3, the verification process, the entire not empty check procedure, and the initial bin full detection is restarted.

A fourth example of a not empty check routine is illustrated in FIG. 28, in which a secondary sensor or a condition is tested at step S28-2. The secondary sensor may be the same kind of transducer as the primary transducer in the same location for redundancy, or the same kind of transducer in a different location for confirmation, or a different kind of transducer in the same or a different location. If it is determined that that the secondary sensor also does not detect a full condition in step S28-3, the process is restarted.

FIG. 29 illustrates a routine for monitoring debris content of the bin 50. The routine is a specific example of an entire integrated process such as the general process discussed with reference to FIG. 13, and includes a specific example including two or more LED emitters and two (or more) collectors disposed in the bin 50. When "80% of dark level" is discussed, the meaning may be (a) 80% of a negative value or (b) 80% of a variable meaning "darkness" rather than a direct measurement of voltage or current. For example, a full dark score may be 100, recorded upon calibration when illumination is off, and a full light score may be 0, recorded upon calibration when illumination is on and unobstructed. 80% of the absolute dark level would be a score of 80 (mostly dark). Alternatively, a light score may be used, which may also take into account accumulated dirt on the sensors and emitters. In this case, 80% of the absolute dark level may be replaced by 20% of the value recorded upon calibration when illumination is on and unobstructed.

At step S29-1, an illumination cycle of a transducer is started. For example, the emitters 755 may be activated and the transmitted signal detected by detectors 760, when it is known (or assumed) that the bin 50 is empty. The thresholds are then checked and set to the detected values at step S29-3. For example, each threshold is set proportional to a dark reading with the lights off.

In a measuring step S29-4, the illumination signal received by each transducer 1 . . . N (e.g., the detectors 760) is measured. In step S44-5, it is determined whether the received illumination is greater than a corresponding set of threshold values. The thresholds are set as a score to be exceeded, but may be set as a negative or low dark current value checked via a greater than or less than comparison. For example, a full bin 50 may register 80% of the absolute dark score in each compartment. The comparison step is intended to detect a nearly absolute dark level, even when the lights are illuminated, when most of the light is being blocked by debris. If one of the receivers is below the threshold (registers a dark level less than expected for a full or near-full bin), the routine returns to step S29-3 (e.g., at least one side is not full or nearing full). Otherwise, the routine proceeds to step S29-6, in which the bin 50 is presumed full and a verification timer is started. At step S29-7, the illumination cycle continues, and the thresholds remain the same, set to a less sensitive level, or decaying slowly. At step S29-8, it is determined whether the received signals are greater than the set of thresholds (e.g., all sensors continue to read more than 80% of a full dark level). If one of the received signals fails the threshold test, the process may return to S29-2 to restart the check process (i.e., the stability test fails, and the entire check restarts, including the "first" detection of all sensors almost dark).

Alternatively, the process returns to S29-7 rather than S29-2, i.e., the stability test is set to register a bin full after a continuous detection of almost full over a certain period time for all the sensors. In this case, rather than restarting the check for a "first" bin full detection, the verify timer may be restarted in step S29-6 when transient non-full conditions are detected. A bin-full state is notified after a consistent full condition is detected.

In either case, after the bin 50 (e.g. each side of the bin 50) has registered an almost full dark condition for the specified verify timer period, checked in step S29-9, a bin-full notification is turned on at step S29-10 in order to indicate to the user that the bin is full. Optionally, at step S29-11, the illumination cycle may be altered or changed, in order to reduce power consumption or to check for an emptied bin 50 more or less often than a full bin 50.

The thresholds for the verification steps are set at step S29-12. The thresholds may be set to a dark level that is less dark than previously employed. The verify level in step S29-12 is not the same as the verification timer of steps S29-6 or S29-9, and in this case is a verification that the bin 50 has not yet been emptied. This level is set to, e.g, 50% of the full dark score, to detect an emptied condition when either sides of the bin 50 has a sufficient increase in detected illumination. A significant amount of material must be removed from the bin 50 for either side to reach a level where a sensor receives, e.g., 50% of illumination received in an unobstructed condition, or 50% greater illumination than when the sensors are in an absolute dark level condition. The thresholds are calibrated or set at step S29-13 on every cycled, e.g., the dark level is set with reference to a no-illumination state. If it is determined at step S29-14 that one received signals is less than the new thresholds (e.g., that all of the sensors no longer register an almost or 80% of dark condition, and at least one of them registers a partially illuminated or 50% dark condition), notification is turned off at step S29-15.

FIG. **30** illustrates a routine for operating transducers, determining the bin-full status of the bin, and turning the bin-full indicators on or off. At step S**30-1**, a timer is initiated by setting a counter to an initial interval (for example, 5 minutes=300 seconds) and decrementing the counter once each second (or other periodic schedule). At step S**30-2**, an initial sensor cycle is run to calibrate the thresholds. A main sensor cycle is run at step S**30-3**, in which each transducer is polled for received illumination signals, and any flags, such as a flag indicating that the bin **50** was sensed as full, are considered. At step S**30-4**, it is determined whether the bin-full flags have been triggered. If not, the counter is reset at step S**30-5**, the bin-full notification is turned off at step S**30-6**, and the routine returns to step S**30-3**. If the result of step S**30-4** is positive, then it is determined at step S**30-7** whether the timer has completed. If not, the routine returns to step S**30-3**; otherwise, the routine proceeds to step S**30-8**, at which the bin-full notification is turned on. The light threshold may then be increased or decreased, as appropriate, at step S**30-9**, for example, the light threshold may be increased from 20% to 50%, and the routine then returns to step S**30-3**.

By increasing the light threshold for comparison with the received illumination signal from the transducers, the sensitivity for turning the bin-full indicators on or off is decreased. The bin-full notification therefore becomes less likely to be turned off, because a more substantial change in the received illumination signal of the transducers is necessary to exceed the increased threshold. As a result, rapid shifting of the bin-full notification from on to off and back again may be avoided.

FIG. **31** illustrates another example of a control routine for the robot **11** and the bin **50**. At step S**31-1**, the variables start_time and grand_total (e.g. a total accumulation of time spent running a cleaning mode) are set to zero (or otherwise set to predetermined initial value). At step S**31-2**, status is checked for each of the variables, and it is determined at step S**31-3** whether the robot **11** is running in a cleaning mode. If the robot **11** is running in the cleaning mode, it is then determined whether the variable start_time has already been recorded (e.g. whether start_time has been assigned a value different from its initialization value). If so, the process returns to step S**31-2**; otherwise, the process proceeds to step S**31-5**, and records the current time to the variable start_time before returning to step S**31-2**. If the result of step S**31-3** is negative, it is then determined at step S**31-6** whether start_time was already recorded. If not, the routine returns to step S**31-2**; otherwise, at step S**31-7**, the current time is recorded as a variable end_time. At step S**31-8**, the accumulated cleaning mode time is calculated by subtracting the value of the variable start_time from the value of the variable end_time. At step S**31-9**, the accumulated cleaning time is then added to the variable grand_total. The variable grand_total represents the total amount of time the robot **11** has spent in cleaning mode since the most recent system reset.

At step S**31-10**, it is determined whether grand total is greater than a milestone value. The milestone may represent a predetermined time period that may be significant, or the milestone may correspond to an arbitrarily chosen time period, for example. If the result of step S**31-10** is negative, the routine returns to step S**31-2**; otherwise, the illumination threshold is incremented at step S**31-11** in order to desensitize measurement of the polled transducer values at step S**31-11**, before the routine returns to step S**31-2**.

The sensitivity of the illumination thresholds for the transducers may be changed or modified based not only on the total amount of time the robot **11** has spent turned on, but instead, in proportion to the amount of time the robot **11** has spent in

the cleaning mode. Furthermore, the criteria of whether the robot **11** is in cleaning mode or not can be defined such that the cleaning mode corresponds to times when a high level of debris intake is detected; or simply when the vacuum or sweeper motors are turned on, for example. False bin-full conditions may arise in situations where the robot **11** traverses a large (but relatively clean) area and therefore does not pick up much debris, or where the robot **11** is turned on for a long period time but does not pick up much debris. The false bin-full conditions may be avoided by focusing on the cleaning mode status rather than general run time.

FIG. **32** illustrates a process of determining bin-fullness in a cleaning bin **50**. The robot **11** is active in step S**32-1** and resets the bin microprocessor **217** in step S**32-2**. If the robot **11** is active (e.g. cleaning) in step S**32-3**, the bin microprocessor **217** reads the bin sensor system **700** (which may hive one or more sensor pairs) in step S**32-4**; otherwise, the bin microprocessor **217** checks if a bin full flag is set in step S**32-18**. In step S**32-5**, the bin microprocessor **217** compares a current sensor reading with a previous sensor reading. If the current sensor reading is much greater than (by a predetermined amount) the previous sensor reading, the bin microprocessor **217** assumes the bin **50** is empty and calibrates the sensor system **700** in step S**33-6** and proceeds to step S**32-7**; otherwise, the bin microprocessor **217** just proceeds to step S**32-7**. In step S**32-7**, the bin microprocessor **217** determines if the robot **11** is active (e.g. cleaning). If the robot **11** is not active, the bin microprocessor **217** checks if a bin full flag is set in step S**32-18**. If the robot **11** is active, the bin microprocessor **217** proceeds to step S**32-8** to set a timer for a predetermined amount of time. The bin microprocessor **217** periodically (or continuously) checks for expiration of the timer. If the timer has not expired, the bin microprocessor **217** proceeds back to step S**32-7** to check for robot activity (without resetting the timer). If the timer has expired, the bin microprocessor **217** checks if a bin full flag is set in step S**32-9**. If the bin full flag is set in step S**32-9**, the bin microprocessor **217** updates the indicator **1130** to notify a robot user that the bin **50** is full and proceeds back to step S**32-7** to check for robot activity. If the bin full flag is not set in step S**32-9**, the bin microprocessor **217** reads the bin sensor system **700** in step S**32-11** and sends the current sensor reading through a low pass filter in step S**32-12**. In step S**32-13**, the bin microprocessor **217** checks if a debris level has charged based on the current sensor reading and adjusts the threshold parameters accordingly. The threshold parameters are set in step S**32-14**. If the current sensor reading is greater than the threshold in step S**32-15**, the bin microprocessor **217** checks if multiple readings exceed the threshold parameters in step S**32-16**. If current sensor reading and subsequent multiple samplings exceed the threshold parameters, the bin full flag is set in step S**32-17** and the bin processor **217** proceeds back to step S**32-7**; otherwise, the bin processor **217** does not set the bin full flag and just proceeds back to step S**32-7**. In step S**32-7**, if the robot **11** is no longer active, the bin processor **217** proceeds to step S**32-18**, where it checks if the bin full flag is set. If the flag is not set, the robot **11** may proceed to a sleep mode in step S**32-22**. If the flag is set, the bin microprocessor **217** updates the indicator **1130** (which may flash, chirp, etc.) to notify a robot user that the bin **50** is full. In step S**32-20**, if the bin **50** is moved by the user, the bin full flag is cleared in step S**32-21** and the robot **11** proceeds to the sleep mode in step S**32-22**; otherwise, the flag is not cleared and the robot **11** just proceeds to the sleep mode in step S**32-23**.

Other details and features combinable with those described herein may be found in the following U.S. patent applications filed concurrently herewith, entitled "CLEANING ROBOT

ROLLER PROCESSING" having assigned Ser. No. 11/751, 413; and "REMOVING DEBRIS FROM CLEANING ROBOTS" having assigned Ser. No. 11/751,470, the entire contents of the aforementioned applications are hereby incorporated by reference.

A number of implementations have been described. Nevertheless, it will be understood that various modifications may be made without departing from the spirit and scope of the disclosure. Accordingly, other implementations are within the scope of the following claims.

What is claimed is:

1. An autonomous coverage robot comprising:
a chassis;
a drive system mounted on the chassis and configured to maneuver the robot;
a cleaning assembly carried by the chassis and comprising:
a cleaning assembly housing; and
at least one driven sweeper coupled to the cleaning assembly housing;
a controller carried by the chassis;
a removable bin attached to the chassis and configured to receive debris agitated by the driven sweeper, the removable bin comprising:
an emitter disposed on an interior surface of the bin; and
a receiver disposed on the interior surface of the bin, and configured to receive a signal emitted by the emitter, the emitter and the receiver disposed such that a threshold level of accumulation of debris in the bin attenuates emissions received by the receiver from the emitter;
and
a bin controller monitoring a signal from the detector and initiating a bin full routine upon determining a bin debris accumulation level requiring service, wherein the emitter and the receiver are disposed proximate to one another on the same interior surface of the bin, the removable bin further comprising:
a vacuum assembly having an at least partially separate entrance path into the bin; and
a plurality of teeth disposed substantially along a mouth of the bin between a sweeper bin portion and a vacuum bin portion housing the vacuum assembly, the teeth configured to strip debris from the rotating sweeper brush, the debris being allowed to accumulate in the sweeper bin portion.

2. The autonomous coverage robot of claim 1 further comprising a diffuser positioned over the emitter to diffuse the emitted signal, the receiver receiving the diffused emissions, wherein accumulation of debris in the bin at least partially blocks the diffused emissions from being received by the receiver.

3. The autonomous coverage robot of claim 2 wherein the emitter comprises an infrared light emitter diffused by a translucent plastic sheet.

4. The autonomous coverage robot of claim 1 wherein the emitter is disposed on a first interior lateral surface of the bin and the receiver is disposed on an opposing, second interior lateral surface of the bin.

5. The autonomous coverage robot of claim 4 wherein the emitter and the receiver are arranged for a determination of debris accumulation within substantially an entire volume of the bin.

6. The autonomous coverage robot of claim 1 further comprising a human perceptible indicator configured to provide an indication that autonomous operation may be interrupted for bin servicing.

7. The autonomous coverage robot of claim 1 further comprising:
a remote indicator in wireless communication with the controller and providing an indication of the cleaning service requirement determined by the controller, wherein the emitter and the receiver are disposed proximate to one another on the same interior surface of the bin.

8. The coverage robot bin-full detection system of claim 1 wherein the emitter comprises an infrared light emitter.

9. The coverage robot bin-full detection system of claim 7 wherein the controller is configured to determine a robot stuck condition and communicates the robot stuck condition to the wireless remote indicator.

10. The coverage robot bin-full detection system of claim 7 wherein the remote indicator is configured to communicate commands to the bin controller.

11. The coverage robot bin-full detection system of claim 7 wherein the bin controller communicates with a controller of the robot.

12. An autonomous coverage robot comprising:
a chassis;
a drive system mounted on the chassis and configured to maneuver the robot;
a cleaning assembly carried by the chassis and comprising:
a cleaning assembly housing; and
at least one driven sweeper brush rotatably coupled to the cleaning assembly housing;
a controller carried by the chassis;
a removable bin attached to the chassis and configured to receive debris agitated by the driven sweeper brush, the removable bin comprising:
an emitter disposed on an interior surface of the bin; and
a receiver disposed remotely from the emitter on the interior surface of the bin, and configured to receive a signal emitted by the emitter, the emitter and the receiver disposed such that a threshold level of accumulation of debris in the bin blocks the receiver from receiving emissions from the emitter; and
a bin controller disposed in the bin and monitoring a signal from the detector and initiating a bin full routine upon determining a bin debris accumulation level requiring service, the bin further comprising:
a vacuum assembly having an at least partially separate entrance path into the bin and
a plurality of teeth disposed substantially along a mouth of the bin between a sweeper bin portion and a vacuum bin portion housing the vacuum assembly, the teeth configured to strip debris from the rotating sweeper brush, the debris being allowed to accumulate in the sweeper bin portion; and
a remote indicator in wireless communication with the controller and providing an indication of the cleaning service requirement determined by the controller.

13. The autonomous coverage robot of claim 12 further comprising a diffuser positioned over the emitter to diffuse the emitted signal, the receiver receiving the diffused emissions, wherein accumulation of debris in the bin at least partially blocks the diffused emissions from being received by the receiver.

14. The autonomous coverage robot of claim 13 wherein the emitter comprises an infrared light emitter diffused by a translucent plastic sheet.

15. The autonomous coverage robot of claim 12 wherein the emitter is disposed on a first interior lateral surface of the bin and the receiver is disposed on an opposing, second interior lateral surface of the bin.

16. The autonomous coverage robot of claim **15** wherein the emitter and the receiver are arranged for a determination of debris accumulation within substantially an entire volume of the bin.

17. The autonomous coverage robot of claim **12** further comprising a human perceptible indicator configured to provide an indication that autonomous operation may be interrupted for bin servicing.

* * * * *