Introduction to *Roomba* and *Create*

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Vacuum cleaning robots

- Earliest related patents issued in 1970's for autonomous lawn mowers
- Hitachi and Sanyo demonstrated prototypes in 1991
- First commercial product released in 2000 by Electrolux of Sweden

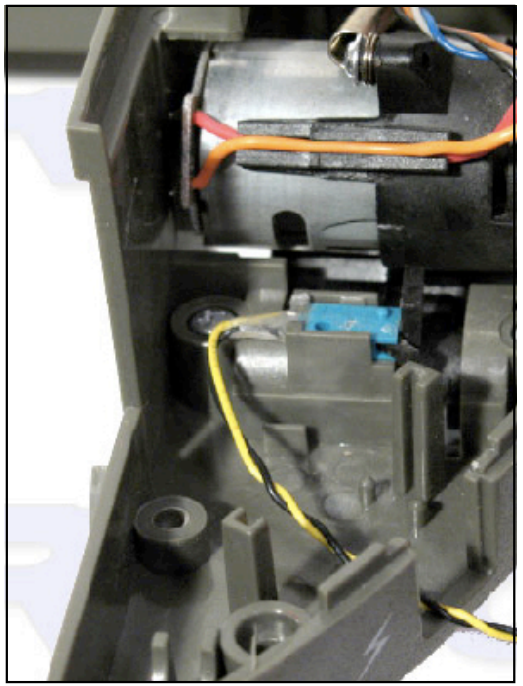
Fiorini and Prassler (2000)

Roomba

- First released in 2002 and patented 2005
- Development took 30 prototypes over twelve years
- Two-millionth *Roomba* sold in 2006
- Now in its fifth generation, the 500 series

Roomba actuators

- Two drive wheels
- Agitator brush
- Side brush
- Vacuum
- (Speaker)



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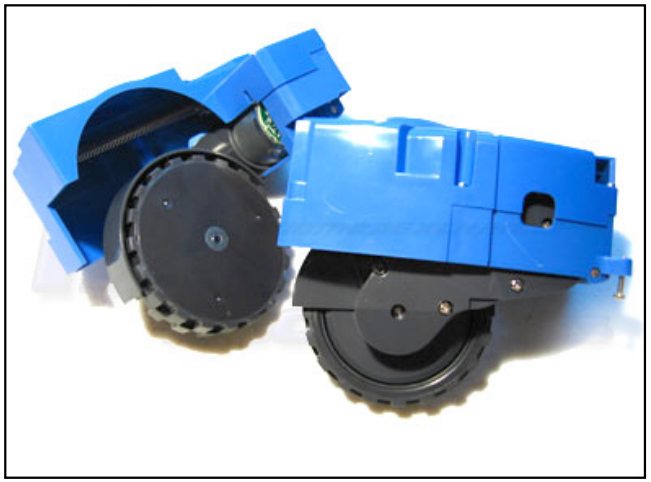
Roomba steering

- Differential steering
  - Each wheel controlled by a distinct motor
  - Allows *Roomba* to spin on the spot



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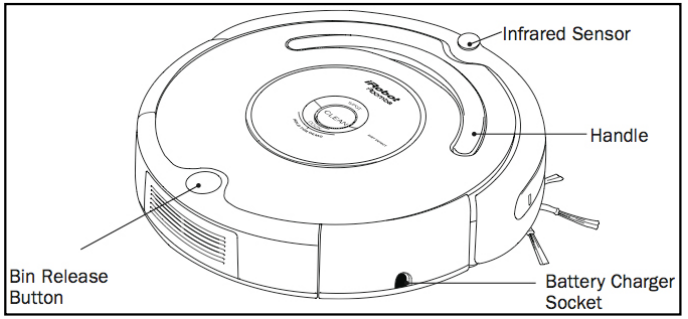
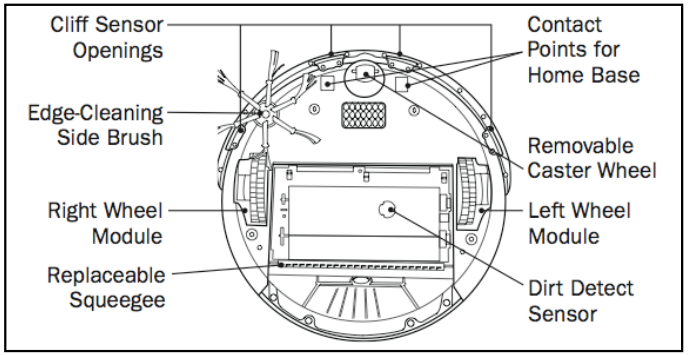
Roomba sensors

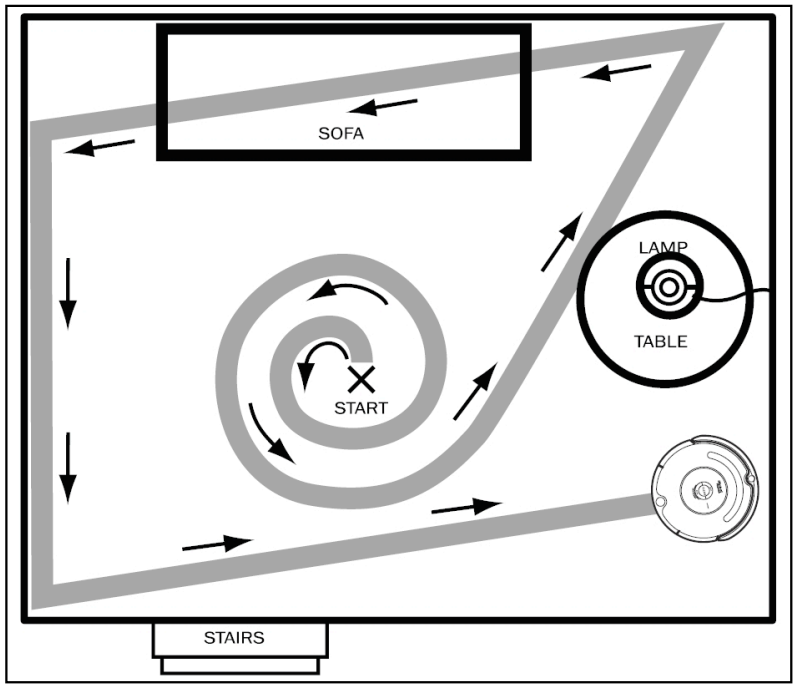
- Over 30 sensors including:
  - Bump and wheel drop (mechanical)
  - Wall and virtual wall (infrared)
  - Wheel overcurrents (electrical)
  - Dirt detector (piezoelectric)





Roomba heuristics

- Spiraling: Cleans a concentrated area
- Wall following: Follows the perimeter of the room
- Room crossing: Crisscrosses the room to achieve full coverage
- Dirt detection: Senses dirt and cleans more intensively



Human-*Roomba* interaction

- Georgia Tech interviewed *Roomba* owners:
  - Most named their *Roomba* and decided on a gender
  - Many "worried" or "felt sorry" for *Roomba* if it became stuck
  - "*Roombarization*" to help and protect *Roomba*

© My Room Bud

Based on the *Roomba* platform

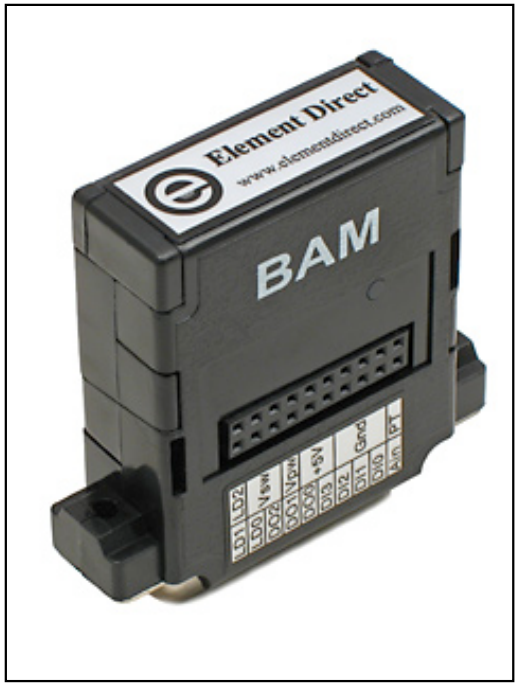
- *Scooba:* Floor washing robot
- *Dirt Dog:* Workshop sweeping robot
- *ConnectR:* "Virtual visiting" robot
- *Create:* Programmable robot

Create

- Almost identical to fourth generation *Roomba* except:
  - No vacuum
  - Extra LEDs and louder speaker
  - Serial port for adding extra actuators, sensors, communications, microprocessor, etc.

Programming *Create*

- Access actuators and 32 sensors over serial port
- *Create* accepts serial commands and sends back sensor packets
- Connect via serial cable or Bluetooth and use any scripting language
- Attach a microcontroller and use a subset of C



Create Open Interface

- Electronic interface: 7-pin Mini-DIN (also present on *Roomba*) and DB-25 connectors
- Software interface: Mode, actuator, song, demo, sensor commands, etc.
- Each command is a one-byte opcode, possibly followed by data bytes

Open Interface modes

- Passive: Request and receive sensor data only
- Safe: Control of actuators, but if a cliff or wheel drop is detected, or the charger is attached, switches to passive mode
- Full: Complete control of actuators, all safety features turned off
- Opcodes 128, 131, and 132

Example

- Start *Create*, switch to full mode, run some commands, then switch to passive:
- `[128] [132] ... [128]`
- *Create* always starts in passive mode

Driving *Create*

- Opcode 137 with four data bytes interpreted as two 16-bit signed values
- First two bytes velocity, second two radius
- Special cases for radius:
  - Straight = hex 8000 or 7FFF
  - Clockwise spin = hex FFFF
  - Counterclockwise spin = hex 0001

Example

- Reverse at a velocity of -200 mm/s while turning at a radius of 500 mm:
- `[137] [255] [56] [1] [244]`
  - Velocity = -200 = hex FF38 = hex FF hex 38 = 255 56
  - Radius = 500 = hex 01F4 = hex 01 hex F4 = 1 244

Reading sensors

- *Create* updates its sensors every 15 ms
- 43 sensor packets representing a sensor or group of sensors
- Use opcode 142 with one data byte to request packets
- Special packet IDs:
  - Specific subgroups: 0 - 5
  - All sensors: 6

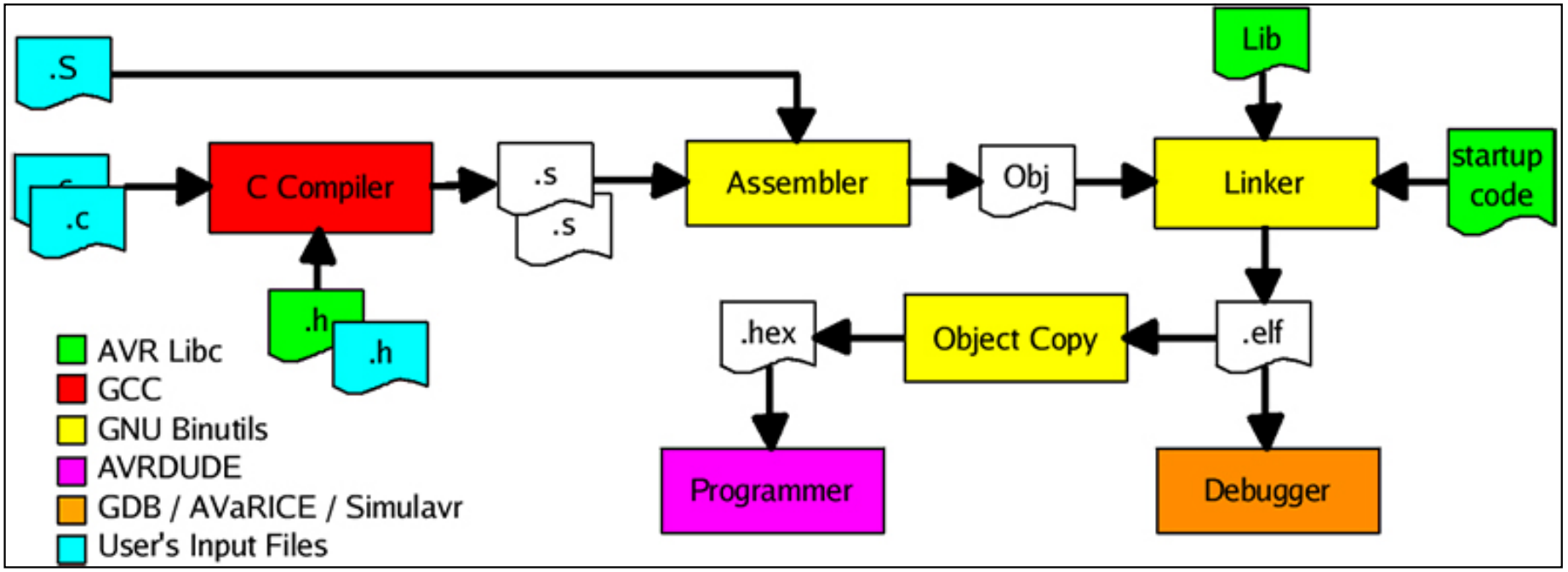
Example

- Get the state of the left cliff sensor:
- `[142] [9]`
  - Cliff sensors are packets 9 - 13

Command Module

- Plugs into cargo bay connector
- Four expansion ports for custom hardware
- Powered by Atmel AVR ATMega168 microcontroller
  - 8-bit RISC architecture with ~18 MHz crystal, 14336 bytes flash memory

AVR-GCC Toolchain



© AVR Freaks

Command Module programming

- Main software components:
  - *avr-gcc*: C compiler
  - *avrdude*: Programmer
- Possible to program in C++, but poorly supported
- Easiest to adapt and extend example code and makefiles
- *oi.h* contains Open Interface definitions

Initialization

```
#include "oi.h"
#include <avr/interrupt.h>
#include <avr/io.h>

void initialize(void)  {
   cli(); // Turn off interrupts

   // Set I/O pins
   DDRB = 0x10;  PORTB = 0xCF;  DDRC = 0x00;
   PORTC = 0xFF;  DDRD = 0xE6;  PORTD = 0x7D;

   // Set baud rate to 57600 bps
   UBRR0 = 19;  UCSR0B = 0x18;  UCSR0C = 0x06;

   // Set up timer 1 to generate an interrupt every 1 ms
   TCCR1A = 0x00;
   TCCR1B = (_BV(WGM12) | _BV(CS12));
   OCR1A = 71;
   TIMSK1 = _BV(OCIE1A);

   sei();  // Turn on interrupts
}
```

Reading sensors

```
#define Sen6Size 52
#define CmdSensors 142

volatile uint8_t sensors_flag = 0;
volatile uint8_t sensors_index = 0;
volatile uint8_t sensors_in[Sen6Size];
volatile uint8_t sensors[Sen6Size];

if(!sensors_flag)  {
   for(temp = 0; temp < Sen6Size; temp++)
      sensors[temp] = sensors_in[temp];
   byteTx(CmdSensors);  byteTx(6);
   sensors_index = 0;  sensors_flag = 1;
}

// Serial receive interrupt to store sensor values
ISR(USART_RX_vect)  {
   if(sensors_flag)  {
       sensors_in[sensors_index++] = UDR0;

       if(sensors_index >= Sen6Size)
         sensors_flag = 0;
   }
}
```

Timer interrupt

```
volatile uint16_t timer_cnt = 0;
volatile uint8_t timer_on = 0;

// Timer 1 interrupt to time delays in ms
ISR(TIMER1_COMPA_vect)  {
   if(timer_cnt > 0)
      timer_cnt--;
   else
      timer_on = 0;
}
```

Send and receive

```
// Transmit a byte over the serial port
void byteTx(uint8_t value)  {
   while(!(UCSR0A & 0x20));  // Do nothing
   UDR0 = value;
}

// Receive a byte from the serial port
uint8_t byteRx(void)  {
   while(!(UCSR0A & 0x80));  // Do nothing

   return UDR0;
}
```

Drive function

```
#define CmdDrive 137

// Send Create drive commands in terms of velocity and radius
void drive(int16_t velocity, int16_t radius)
{
   byteTx(CmdDrive);
   byteTx((uint8_t)((velocity >> 8) & 0x00FF));
   byteTx((uint8_t)(velocity & 0x00FF));
   byteTx((uint8_t)((radius >> 8) & 0x00FF));
   byteTx((uint8_t)(radius & 0x00FF));
}
```

Other options

- *Create* and *Roomba* can be controlled by these platforms via serial cable or Bluetooth and/or simulated (in part):
  - Cogmation robotSuite
  - Microsoft Robotics Developer Studio
  - Player/Stage/Gazebo

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