

# Practical Computerized Home Automation

BRUCE MOMJIAN



Home automation is computer control of home devices, typically electrical. Using inexpensive hardware and open source software, it is possible to programmatically control many devices in your home, providing ease and enjoyment for your family.

*Creative Commons Attribution License,*

*images are copyright of their respective websites <http://momjian.us/presentations>*

*Last updated: February, 2018*

# Outline

1. What is computerized automation?
2. Evaluating technologies
3. Sample deployment
4. Device programming basics
5. What is success?
6. Home automation applications

# 1. What Is Computerized Automation?

## Non-Programmatic Automation

- ▶ Timers
- ▶ Clapper
- ▶ Dawn/Dusk Sensors
- ▶ Motion Sensors

# Programmatic Automation

- ▶ Device behavior can be combined
- ▶ No distance limitations
- ▶ Activity detection
- ▶ Fully programmable / scriptable
- ▶ Access to external data

## 2. Evaluating Technologies: Home Networks

- ▶ Wired telephone
- ▶ Cordless telephone (900MHz, 2.4GHz, 5.8 GHz, 1.9GHz)
- ▶ Wired local area network (Ethernet)
- ▶ Wireless local area network (802.11)
- ▶ Electrical
- ▶ New wireless networks

# Home Network Choices

- ▶ Power Line Control (PLC)
  - ▶ X10: signal transmitted at 60 Hz zero-crossings (120 kHz)
  - ▶ Universal Power Bus (UPB): out-of-band signal (4-40 kHz)
- ▶ Radio frequency (wireless)
  - ▶ Z-Wave: 900 MHz
  - ▶ Zigbee: 900 MHz and 2.4GHz (IEEE standard 802.15.4)
- ▶ Hybrid
  - ▶ Insteon: out-of-band PLC (131 kHz) and radio frequency (900MHz), plus X10 support

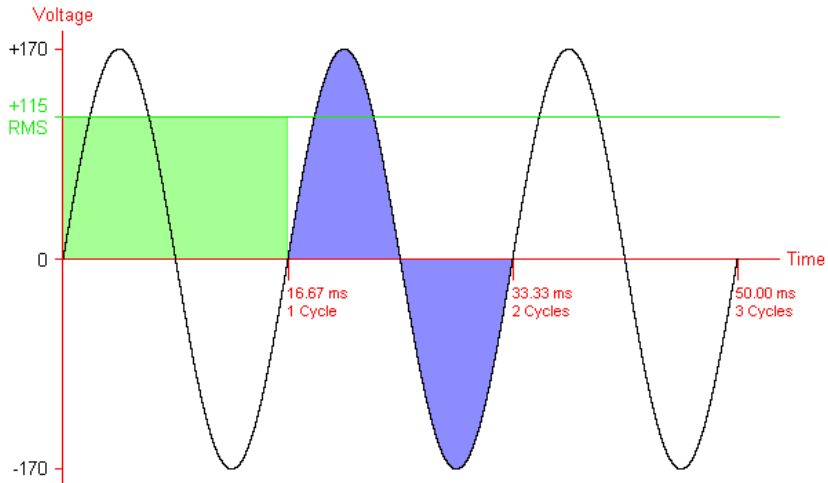
[http://www.smarthome.com/INSTEON\\_comparison.html](http://www.smarthome.com/INSTEON_comparison.html)

<http://www.sgiclearinghouse.org/Technologies?q=node/2126>

# Choosing a Home Network Technology

- ▶ Open source computer control
  - ▶ heyu supports X10
  - ▶ MisterHouse (Perl-based) supports all listed technologies
- ▶ Availability of devices
  - ▶ electrical plug control
  - ▶ wireless remotes
  - ▶ chimes
  - ▶ sensors
  - ▶ doors, locks
  - ▶ thermostats/HVAC
  - ▶ 220-volt control
- ▶ Signal reliability (X10 is the worst)
- ▶ Technology longevity (X10's future is uncertain)
- ▶ Simplicity of device replacement
- ▶ Cost
- ▶ Subset of Internet of Things

### 3. Sample Deployment: X10: Electrical Signal Basics, 60 Hertz





# Adding A Signal

## Complementary Pair Data

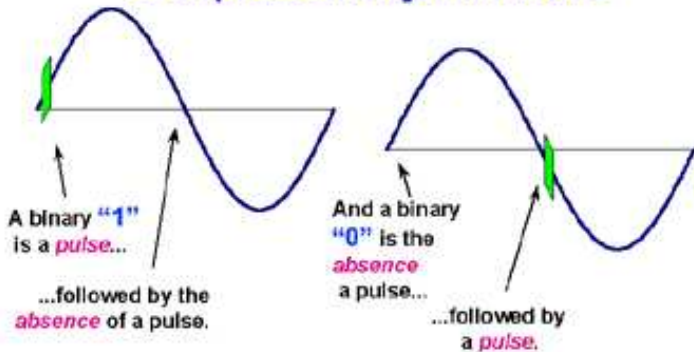
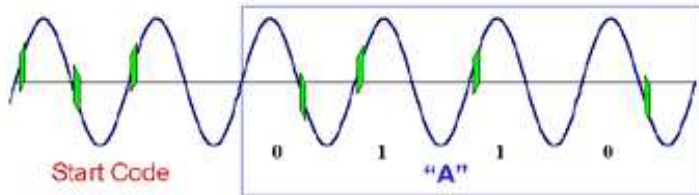


Figure 2

<http://www.pcguides.com/ref/power/ext/basicsACDC-c.html> and following

# Multiple Bits

Immediately after a **“Start Code”**,  
a **“Letter Code”** is sent. (4 cycles)



<b>A = 0110</b>	<b>E = 0001</b>	<b>I = 0111</b>	<b>M = 0000</b>
<b>B = 1110</b>	<b>F = 1001</b>	<b>J = 1111</b>	<b>N = 1000</b>
<b>C = 0010</b>	<b>G = 0101</b>	<b>K = 0011</b>	<b>O = 0100</b>
<b>D = 1010</b>	<b>H = 1101</b>	<b>L = 1011</b>	<b>P = 1100</b>

Figure 3

# Oscilloscope Showing Zero

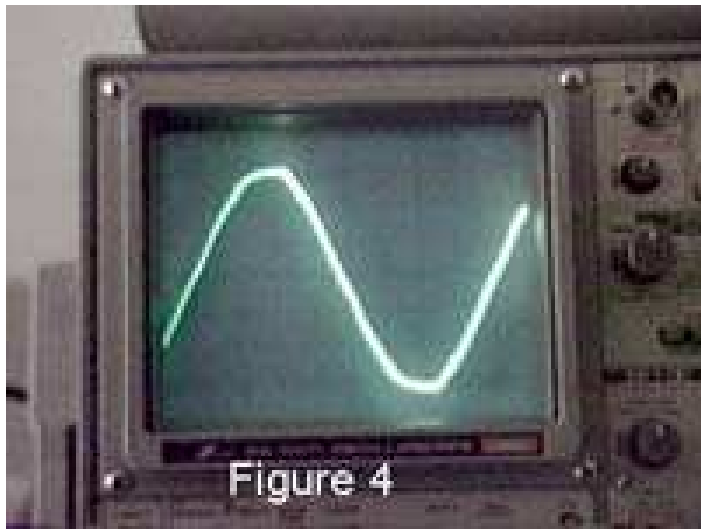
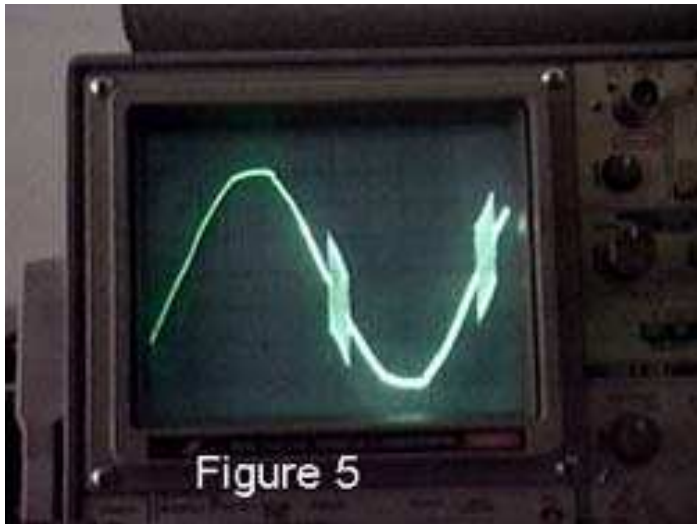


Figure 4

# Oscilloscope Showing One



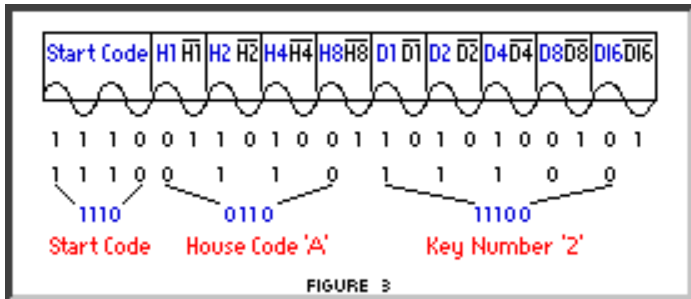
# The X10 Standard

X10 is an international and open industry standard for communication among electronic devices used for home automation.

- ▶ Designed in 1975 by Pico Electronics of Glenrothes, Scotland
- ▶ Uses a 120 kHz carrier transmitted as bursts during the relatively quiet zero crossings of the 60 Hz AC alternating current waveform
- ▶ One bit is transmitted per zero crossing
- ▶ 120 bits per second transmission rate
- ▶ 256 maximum device codes
- ▶ 16 house codes, A-P; 16 devices per house code, 1-16

*[http://en.wikipedia.org/wiki/X10\\_\(industry\\_standard\)](http://en.wikipedia.org/wiki/X10_(industry_standard))*

# X10 Protocol



<http://www.x10.com/support/technology1.htm> and following

# X10 Protocol

HOUSE CODES					KEY CODES					
	H1	H2	H4	H8	D1	D2	D4	D8	D16	
A	0	1	1	0	1	0	1	1	0	0
B	1	1	1	0	2	1	1	1	0	0
C	0	0	1	0	3	0	0	1	0	0
D	1	0	1	0	4	1	0	1	0	0
E	0	0	0	1	5	0	0	0	1	0
F	1	0	0	1	6	1	0	0	1	0
G	0	1	0	1	7	0	1	0	1	0
H	1	1	0	1	8	1	1	0	1	0
I	0	1	1	1	9	0	1	1	1	0
J	1	1	1	1	10	1	1	1	1	0
K	0	0	1	1	11	0	0	1	1	0
L	1	0	1	1	12	1	0	1	1	0
M	0	0	0	0	13	0	0	0	0	0
N	1	0	0	0	14	1	0	0	0	0
O	0	1	0	0	15	0	1	0	0	0
P	1	1	0	0	16	1	1	0	0	0
				All Units Off	0	0	0	0	0	1
				All Lights On	0	0	0	0	1	1
				On	0	0	1	0	1	
				Off	0	0	1	1	1	
				Dim	0	1	0	0	1	
				Bright	0	1	0	1	1	
				All Lights Off	0	1	1	0	1	
				Extended Code	0	1	1	1	1	
				Hail Request	1	0	0	0	1	①
				Hail Acknowledge	1	0	0	1	1	
				Pre-Set Dim	1	0	1	X	1	②
				Extended Data (analog)	1	1	0	0	1	③
				Status-on	1	1	0	1	1	
				Status-off	1	1	1	0	1	
				Status Request	1	1	1	1	1	

FIGURE 4

# X10 Limitations

- ▶ Requires 0.75 seconds to transmit a command
- ▶ Poor propagation in split-phase electricity distribution
- ▶ Affected by line noise from other devices
- ▶ Affected by X10 signals from other buildings



# The Split-Phase Electricity Distribution Problem

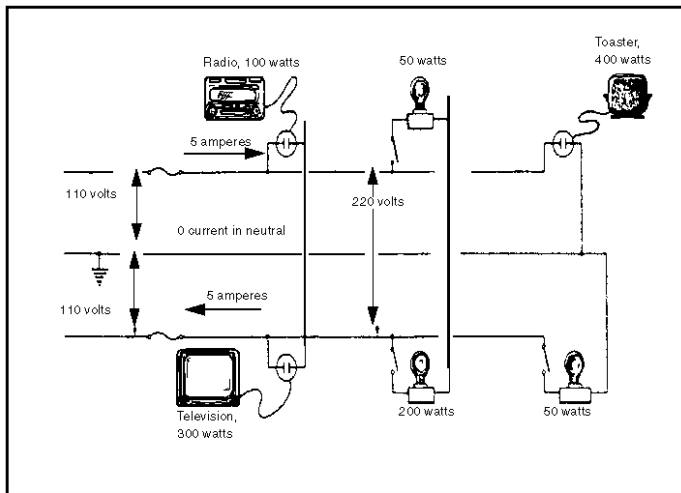


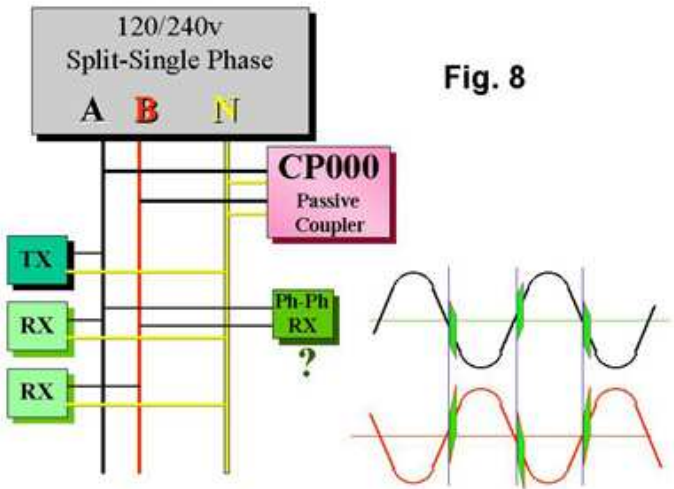
Figure 3-2. Circuit balancing

<http://www.globalsecurity.org/military/library/policy/army/fm/5-424/chap3.htm>

# Allowing Split-Phase Electricity Distribution Propagation, With Amplification



# Phase Coupling



<http://www.hometoys.com/htinews/jun97/articles/kingery/kingery3.htm>

# Reducing Line Noise



I need to use this because my UPS dampens X10 signals. You also might want to block X10 signals from coming into your house, or you can use unique house codes.

# Wall Switch



# Flat Switch



# Three-Way Switch



Three-way switches are difficult to install because the X10 detection module must be on the *power* side of the switch, not the

# Wireless Wall Switch





# Wireless Receiver



# Wireless Remote



# Wireless Remote



# Lamp/Appliance Control



# Pool



The pool pump runs longer when the weather is warmer. The server gets the outside air temperature from a weather web site and turns the pool pump on and off at the proper times.

# Heyu

## NAME

heyu - control program for the X10 CM11A serial interface

## SYNOPSIS

```
heyu address unit-specifier
heyu date
heyu erase
heyu function unit-specifier state
heyu info
heyu help
heyu monitor
heyu preset unit-specifier preset-dim
heyu reset [housecode]
heyu setclock
heyu status [unit-specifier]
heyu stop
heyu turn unit-specifier state [amount]
heyu upload [check]
heyu version
```

# Computer/Power Line Interface



# Monitoring

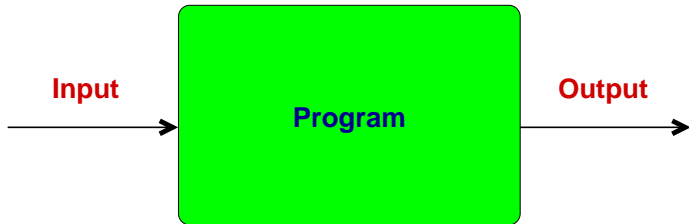
```
7/6 at 05:40:49 address unit 8 : housecode d (entrymotion_dusk)
7/6 at 05:40:49 function      Off : housecode d unit 8 (entrymotion_dusk)
7/6 at 20:35:57 address unit 8 : housecode d (entrymotion_dusk)
7/6 at 20:35:57 function      On  : housecode d unit 8 (entrymotion_dusk)
7/6 at 22:05:46 address unit 3 : housecode f (catherine)
7/6 at 22:05:46 function      Off : housecode f unit 3 (catherine)
7/5 at 23:18:20 address unit 13 : housecode i (remotebed2)
7/5 at 23:18:21 function      Off : housecode i unit 13 (remotebed2)
```



# Auto-Response to Activity

```
x10 monitor | while read LINE
do
    echo "$LINE" >>/var/log/x10
    case "$LINE" in
        *" Off : "*" (remotedbed)"*)
            x10off $(x10group 1 | egrep -v '^entrytable$')
            ;;
        # is it dusk?
        *" On : "*" (entrymotion_dusk)"*)
            if [ -f /u/x10/wait_for_dusk ]
            then    rm /u/x10/wait_for_dusk
                   x10on 1
                   echo "x10on masterbath laundry" | at now +45 minutes
            fi
            ;;
        *" On : "*" (kitchen_chime"*)"*)
            say "We are ready to eat."
            daemon -cf sbplay bell.wav 50
            sleep 2
            ;;
    esac
done
```

## 4. Device Programming Basics: Software Control



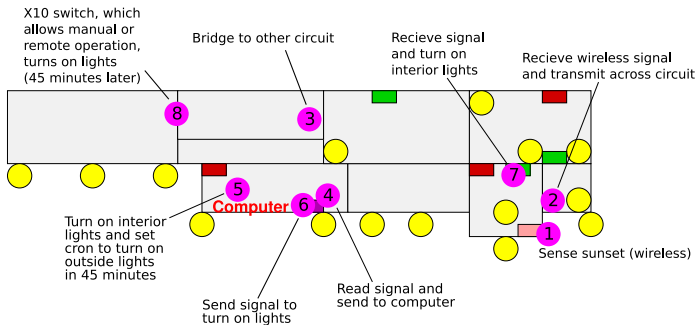
# Inputs

- ▶ User commands
- ▶ Clock/Timer
- ▶ Dawn/Dusk sensors
- ▶ Wireless remotes
- ▶ Caller Id
- ▶ Telephone Dialing
- ▶ Web sites, e.g. outside temperature

# Outputs

- ▶ Lights
- ▶ Motors
- ▶ Appliances, e.g. coffee maker
- ▶ Sounds
- ▶ Network broadcast messages
- ▶ Slideshow

# Sample Application: Dusk



## 5. What Is Success?

- ▶ Adding home automation changes your family's home environment
- ▶ Start slow; make incremental changes
- ▶ Accept that some home automation tasks are impossible
- ▶ You have succeeded when a family member asks for a home automation addition

Smart-Home Gadgets Still a Hard Sell, *Wall Street Journal*,

<http://on.wsj.com/1ligx05>

# Challenges

- ▶ Change
- ▶ Reliable operation
- ▶ Device longevity
- ▶ Maintenance
- ▶ Cost, coordination server
- ▶ Security/privacy

Nest Thermostat Bug Leaves Users Cold, *BBC News*, <http://www.bbc.com/news/technology-35311447>

## 6. Home Automation Applications: Telephone Interface





# Telephone Logging

*AT#CID=1*

```
Wed Jul 8 21:34:00 EDT 2009 DATE = 0708
Wed Jul 8 21:34:00 EDT 2009 TIME = 2134
Wed Jul 8 21:34:00 EDT 2009 NMBR = 6107429657
Wed Jul 8 21:34:00 EDT 2009 NAME = PENNSYLVANIA
```

Lookup phone number in contact directory.

```
Wed Jul 8 21:34:04 EDT 2009 Bruce and Christine Momjian
from Bruce's cell phone (610) 742-9657
```

Optionally sound X10 chime if phone call is from an important phone number.

# Telephone Dialing

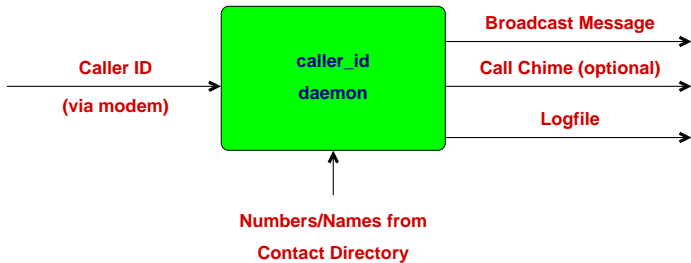
Dial phone number from contact directory:

```
ATDT16107429657
```

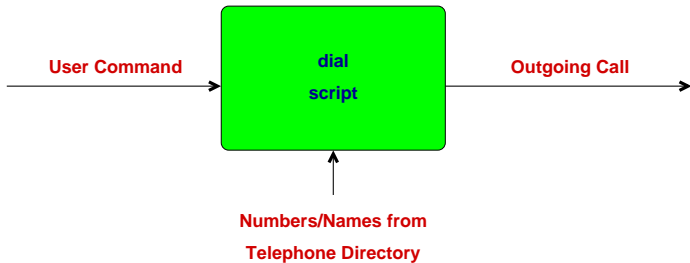
```
Tue Apr 7 14:57:26 EDT 2009 16107429657 Bruce and  
Christine Momjian to Bruce's cell phone
```

This can also be used to automatically dial recently received calls using the log.

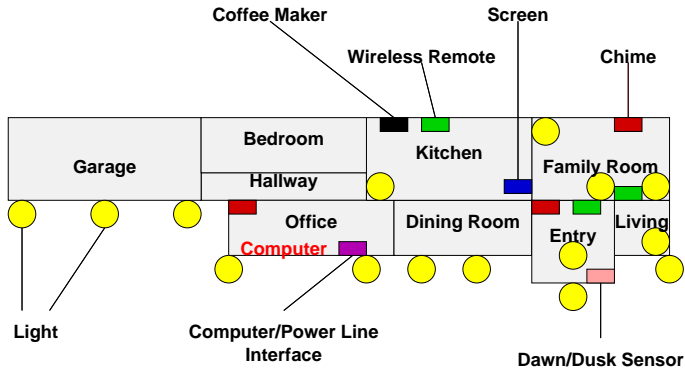
# Telephone Notification



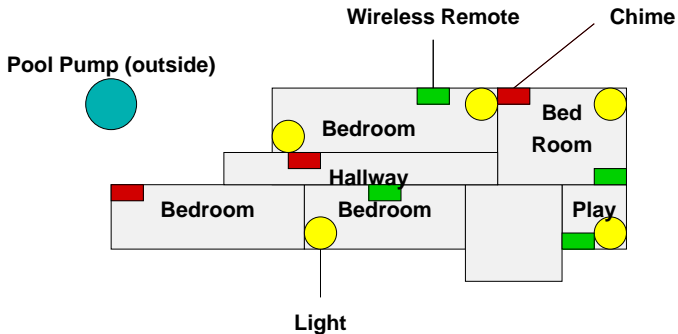
# Outgoing Calls



# Home Application: First Floor



# Home Application: Second Floor



# Heyu

X10 devices are controlled and monitored using the X10 CM11a computer interface device and the open source *heyu* control software. For heyu information, see <http://www.heyu.org/>. Heyu can be customized by defining devices in `~/x10config`:

```
remotedbed      I 1      # downstairs remote alloff
entrytable      I 2
bookcase        I 3
couch           I 4
tiffany         I 5
schoolroom      I 6
fireplace       I 7
laundry         I 8
wireless        I 9      # wireless outlet, makes click noise
masterbed       I 10
...

```

# Heyu Wrapper Script

Instead of:

```
$ heyu turn couch on
```

a script can be created:

```
$ x10on couch
```

The script can handle multiple devices:

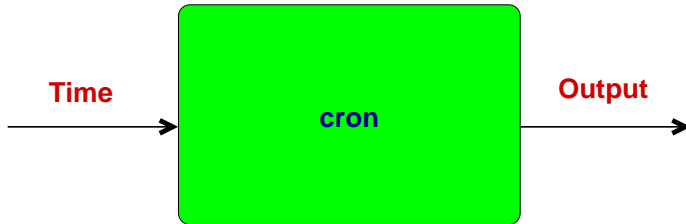
```
$ x10on tiffany bookcase
```

and groups of devices can be defined:

```
$ x10off video
```



# Simple Time-Based Activity



# Crontab Scheduler

```
0 7 * * *      root x10on slideshow
0 11 * * *     root x10on decor
0 12 * * *     root touch /u/x10/wait_for_dusk
0 14 * * *     root x10on bathroom
30 20 * * *    root x10on boyscolor catherine

# fade
30 21 * * *    root x10dim entrytable decor bathroom

# off
0 21 * * *     root x10off bookcase
0 23 * * *     root frontlights off; x10off decor tiffany
0 0 * * *      root x10off `x10group 1 | egrep -v '^entrytable$'`
0 0 * * *      root touch /u/x10/wait_for_dawn
59 0 * * *     root x10dimoff_slow laundry
59 1 * * *     root ! is_tz_fallback && x10alloff
```

# Dawn/Dusk Activity



# Acting on Events (Dusk)

```
x10 monitor | while read LINE
do
    echo "$LINE" >>/var/log/x10

    case "$LINE" in
        # is it dusk?
        *" On : ""(entrymotion_dusk)*"
            if [ -f /u/x10/wait_for_dusk ]
            then    rm /u/x10/wait_for_dusk
                    x10on 1
                    echo "heyu turn masterbath on;
                        heyu turn laundry on" |
                        at now +45 minutes

            fi
        ;;
    esac
done
```

# X10 Already Supports Wireless Remotes



# Coffee Maker

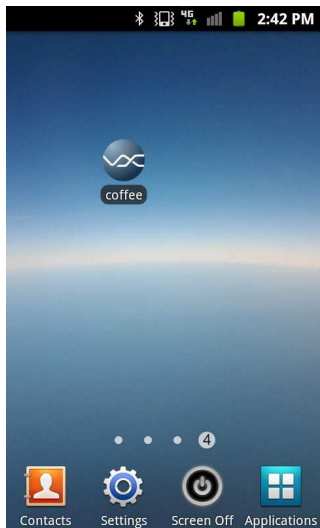


# Coffee Maker Timer



```
*" On : "*" (coffeepot "*" ) "*"
  echo "heyu turn coffeepot off" | at now +15 minutes
  ;;
```

# Smartphone Coffee Control

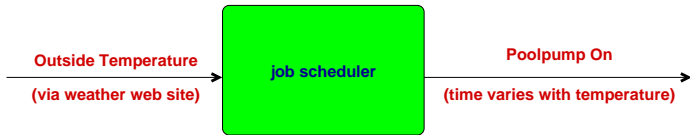




# Implementing Smartphone Coffee Control

1. Install an SSH client on the smartphone (VX Connectbot)
2. Setup an SSH key to avoid password prompting
3. Use *post-log automation* to issue the *heyu* shell command to turn on the coffee, and logout

# Pool Pump



A script allows scheduled pump control with manual override.

# Family Activity Screen



Screen is shown on a dummy display and also on laptops throughout the house. Source available at <http://code.google.com/p/infodisp>.

# Time to Eat



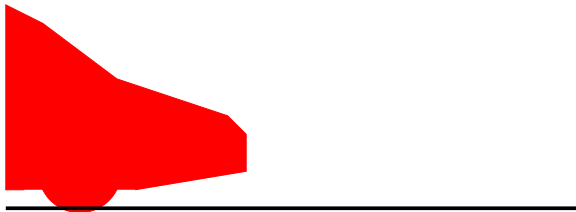
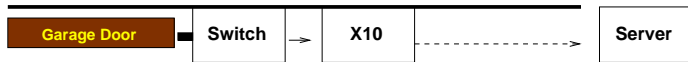
# Garage Entry Detection

- ▶ Light
- ▶ Motion
- ▶ Distance
- ▶ Garage door activation
- ▶ Garage door position

# Detection Challenges

- ▶ Taking out the trash
- ▶ Leaving vs. arriving

# Garage Door Position Detection



# Garage Door Position Detection





# Garage Door Position Detection



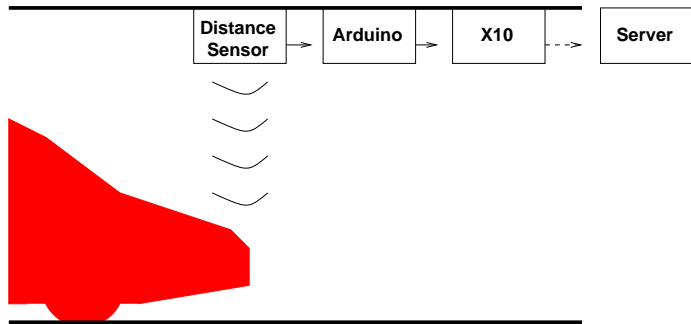
# Garage Door Closed



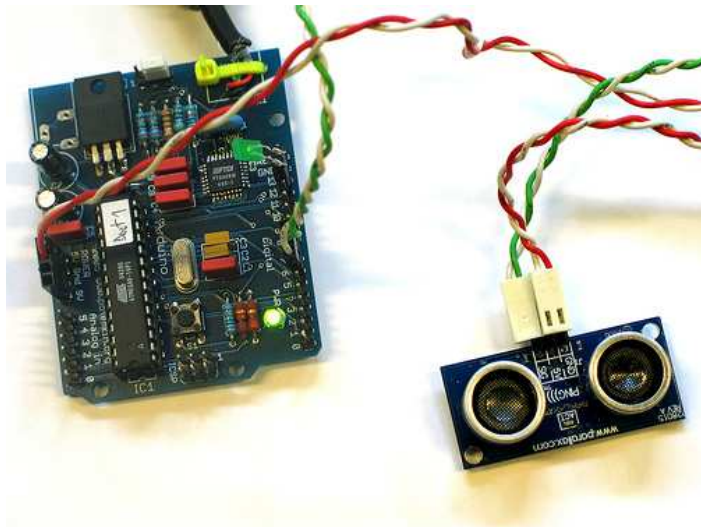
# Garage Door Open



# Distance Detection



# Arduino Distance Detection: Ping Ultrasonic Range Finder



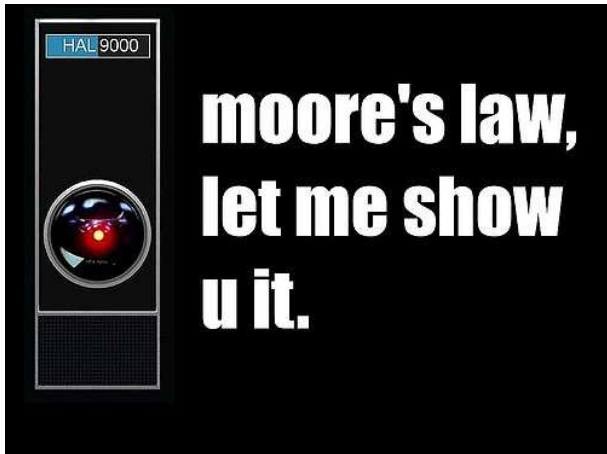
# The Solution



# Arrival Reporting

- ▶ Turn on outside lights
- ▶ Issue message that someone has arrived
- ▶ Report who was in the car (what MAC address disappeared when the car left)
- ▶ Van has returned with Christine

# Conclusion



Another presentation: <http://www.ushomeautomation.com/Presentations/TCF2011>

<http://momjian.us/presentations>

<https://www.flickr.com/photos/cornelii/>