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Interoperability in Internet of Things

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Current Challenges in IoT

- ✓ Large Scale of Co-Operation:
  - The cooperation and coordination of millions of distributed devices are required on Internet
- ✓ Global Heterogeneity:
  - Heterogeneous IoT devices and their subnets
- ✓ Unknown IoT Device Configuration:
  - The different configuration modes for IoT devices which come from unknown owners
- ✓ Semantic Conflicts:
  - Different processing logics applied to same IoT networked devices or applications.

Source: G. Xiaoand, J. Guo, Li Da Xu, and Z. Gong, "User Interoperability With Heterogeneous IoT Devices Through Transformation," *IEEE Trans. Indust. Informatics*, vol. 10, no. 2 pp. 1486-1496, May 2014.

What is Interoperability?

- ✓ Interoperability is a characteristic of a product or system, whose interfaces are completely understood, to work with other products or systems, present or future, in either implementation or access, without any restrictions.
  - Communicate meaningfully
  - Exchange data or services

Source: "Definition of Interoperability". dedicated website for a Definition of Interoperability at interoperability-definition.info. Copyright AFUL under CC BY-SA.

Why Interoperability is Important in Context of IoT?

✓ To fulfill the IoT objectives

- Physical objects can interact with any other physical objects and can share their information
- Any device can communicate with other devices anytime from anywhere
- Machine to Machine communication(M2M), Device to Device Communication (D2D), Device to Machine Communication (D2M)
- Seamless device integration with IoT network

Why Interoperability is required?

- ✓ Heterogeneity
  - Different wireless communication protocols such as ZigBee (IEEE 802.15.4), Bluetooth (IEEE 802.15.1), GPRS, 6LowPAN, and Wi-Fi (IEEE 802.11)
  - Different wired communication protocols like Ethernet (IEEE 802.3) and Higher Layer LAN Protocols (IEEE 802.1)
  - Different programming languages used in computing systems and websites such as JavaScript, JAVA, C, C++, Visual Basic, PHP, and Python
  - Different hardware platforms such as Crossbow, NI, etc.

Why Interoperability is required? (Contd.)

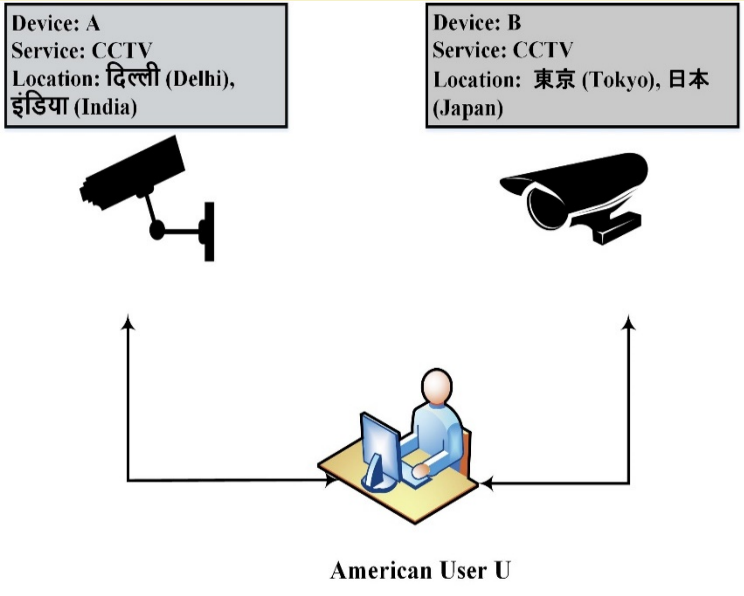
- Different operating systems
  - As an example for sensor node: TinyOS, SOS, Mantis OS, RETOS, and mostly vendor specific OS
  - As an example for personal computer: Windows, Mac, Unix, and Ubuntu
- Different databases: DB2, MySQL, Oracle, PostgreSQL, SQLite, SQL Server, and Sybase
- Different data representations
- Different control models
- Syntactic or semantic interpretations

Different Types of Interoperability?

- ✓ User Interoperability
  - Interoperability problem between a user and a device
- ✓ Device Interoperability
  - Interoperability problem between two different devices

Example of Device and User Interoperability

- ✓ Using IoT, both A and B provide a real-time security service
- ✓ A is placed at Delhi, India, while B is placed at Tokyo, Japan
- ✓ A, B, U use Hindi, Japanese, and English language, respectively
- ✓ User U wants real-time service of CCTV camera from the device A and B



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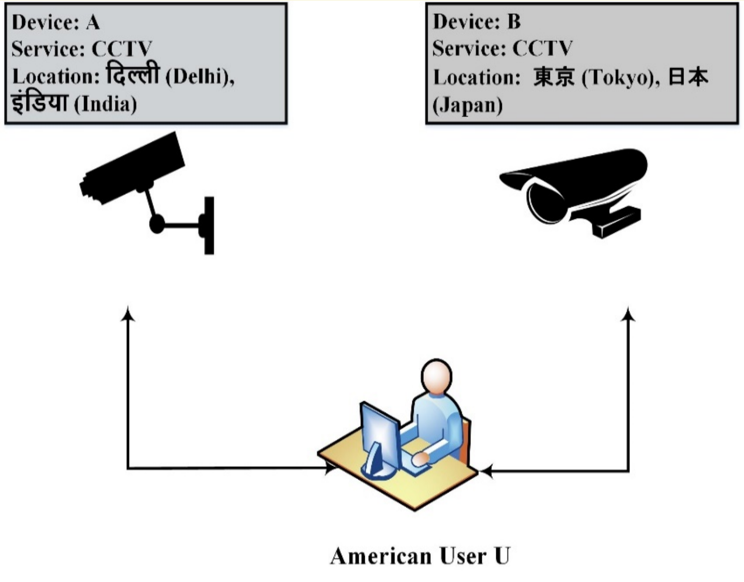
Example of Device and User Interoperability

Problems are listed below

- ✓ The user does not know the devices A and B
- ✓ Devices A and B are different in terms of syntactic and semantic notions
- ✓ Therefore, it is difficult to find CCTV device
- ✓ User U can't understand the service provided by A and B
- ✓ Similarly, A and B do not mutually understand each other



G. Xiaoand, J. Guo, Li Da Xu, and Z. Gong, "User Interoperability With Heterogeneous IoT Devices Through Transformation," *IEEE Trans. Indust. Informatics*, vol. 10, no. 2 pp. 1486-1496, May 2014.

User Interoperability

The following problems need to be solved

- ✓ Device identification and categorization for discovery
- ✓ Syntactic interoperability for device interaction
- ✓ Semantic interoperability for device interaction

Device identification and categorization for discovery

There are different solutions for generating unique address

- ✓ Electronic Product Codes (EPC)
- ✓ Universal Product Code (UPC)
- ✓ Uniform Resource Identifier (URI)
- ✓ IP Addresses
    - IPv6

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Device identification and categorization for discovery (Contd.)

There are different device classification solutions

- ✓ United Nations Standard Products and Services Code (UNSPSC) *
  - an open, global, multi-sector standard for efficient, accurate, flexible classification of products and services.
- ✓ eCl@ss **
  - The standard is for classification and clear description of cross-industry products

Reference: * http://www.unspsc.org/, **http://www.eclass.eu/

Syntactic Interoperability for Device Interaction

- ✓ The interoperability between devices and device user in term of message formats
- ✓ The message format from a device to a user is understandable for the user’s computer
- ✓ On the other hand, the message format from the user to the device is executable by the device

Syntactic Interoperability for Device Interaction (Contd.)

Some popular approaches are

- ✓ Service-oriented Computing (SOC)-based architecture
- ✓ Web services
- ✓ RESTful web services
- ✓ Open standard protocols such as IEEE 802.15.4, IEEE 802.15.1, and WirelessHART*
- ✓ Closed protocols such as Z-Wave*

*But these standards are incompatible with each other

Syntactic Interoperability for Device Interaction (Contd.)

- ✓ Middleware technology
  - Software middleware bridge
  - Dynamically map physical devices with different domains
  - Based on the map, the devices can be discovered and controlled, remotely
- ✓ Cross-context syntactic interoperability
  - Collaborative concept exchange
  - Using XML syntax

Semantic Interoperability for Device Interaction

- ✓ The interoperability between devices and device user in term of message's meaning
- ✓ The device can understand the meaning of user's instruction that is sent from the user to the device.
- ✓ Similarly, the user can understand the meaning of device's response sent from the device

Semantic Interoperability for Device Interaction (Contd.)

Some popular approaches

✓ Ontology

- Device ontology
- Physical domain ontology
- Estimation ontology

Ontology-based solution is limited to the defined domain /context

Source: G. Xiaoand, J. Guo, Li Da Xu, and Z. Gong, "User Interoperability With Heterogeneous IoT Devices Through Transformation," *IEEE Trans. Indust. Informatics*, vol. 10, no. 2 pp. 1486-1496, May 2014.

Semantic Interoperability for Device Interaction (Contd.)

- ✓ Collaborative conceptualization theory
  - Object is defined based on the collaborative concept, which is called cosign
  - The representation of a collaborative sign is defined as follows:
  - cosign of a object = (A, B, C, D), where A is a cosign internal identifier, B is a natural language, C is the context of A, and D is a definition of the object
  - As an example of CCTV, cosign = (1234, English, CCTV, “Camera Type: Bullet, Communication: Network/IP, Horizontal Resolution: 2048 TVL”)
- ✓ This solution approach is applicable for different domains/contexts

Device Interoperability

Solution approach for device interoperability

✓ Universal Middleware Bridge (UMB)

- Solves seamless interoperability problems caused by the heterogeneity of several kinds of home network middleware
- UMB creates virtual maps among the physical devices of all middleware home networks, such as HAVI, Jini, LonWorks, and UPnP
- Creates a compatibility among these middleware home networks

source: K.-D. Moon, Y.-H. Lee, C.-E. Lee, and Y.-S. Son, "Design of a universal middleware bridge for device interoperability in heterogeneous home network middleware," IEEE Trans. Consum. Electron., vol. 51, no. 1, pp. 314–318, Feb. 2005.

Device Interoperability (Contd.)

UMB consists

- ✓ UMB Core (UMB-C)
- ✓ UMB Adaptor (UMB-A)

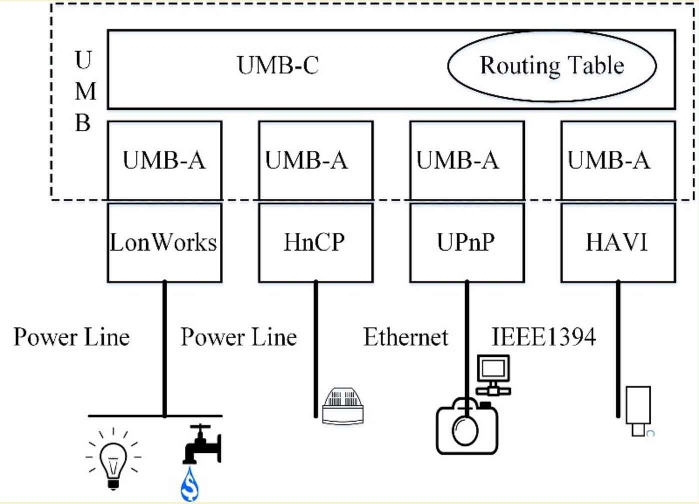

Fig 1: The Architecture of Universal Middleware Bridge

Image source: K.-D. Moon, Y.-H. Lee, C.-E. Lee, and Y.-S. Son, “Design of a universal middleware bridge for device interoperability in heterogeneous home network middleware,” IEEE Trans. Consum. Electron., vol. 51, no. 1, pp. 314–318, Feb. 2005.

Device Interoperability (Contd.)

✓ UMB Adaptor

- UMB-A converts physical devices into virtually abstracted one, as described by Universal Device Template(UDT)
- UDT consists of a Global Device ID, Global Function ID, Global Action ID, Global Event ID, and Global Parameters
- UMB Adaptors translate the local middleware's message into global metadata's message

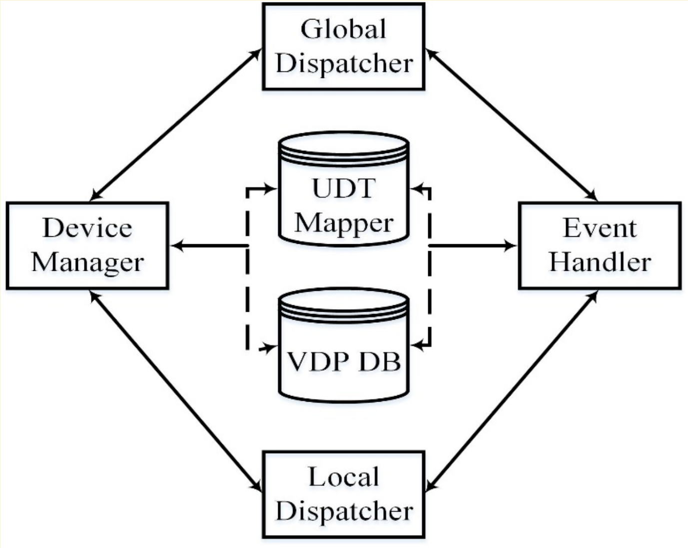

Fig 2: The Structure of UMB-A

Source: K.-D. Moon, Y.-H. Lee, C.-E. Lee, and Y.-S. Son, "Design of a universal middleware bridge for device interoperability in heterogeneous home network middleware," IEEE Trans. Consum. Electron., vol. 51, no. 1, pp. 314–318, Feb. 2005.

Device Interoperability (Contd.)

- ✓ UMB Core
  - The major role of the UMB Core is routing the universal metadata message to the destination or any other UMB Adaptors by the Middleware Routing Table (MRT)

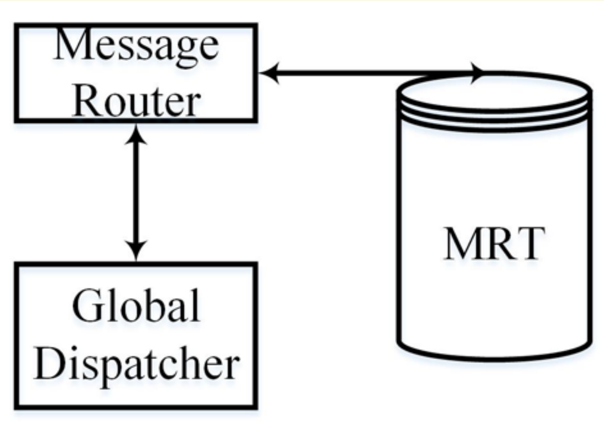

Fig 3: The Structure of UMB-C

Source: K.-D. Moon, Y.-H. Lee, C.-E. Lee, and Y.-S. Son, “Design of a universal middleware bridge for device interoperability in heterogeneous home network middleware,” IEEE Trans. Consum. Electron., vol. 51, no. 1, pp. 314–318, Feb. 2005.

Device Interoperability (Contd.)

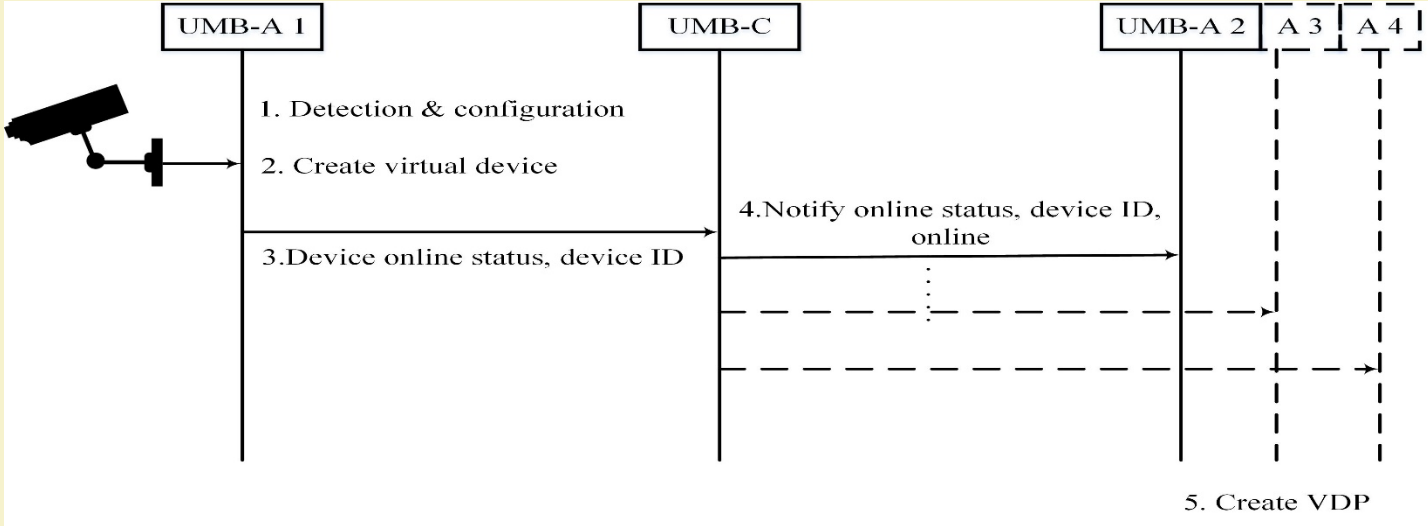

Fig 4: Flow when a new device is plugged in

Source: K.-D. Moon, Y.-H. Lee, C.-E. Lee, and Y.-S. Son, “Design of a universal middleware bridge for device interoperability in heterogeneous home network middleware,” IEEE Trans. Consum. Electron., vol. 51, no. 1, pp. 314–318, Feb. 2005.

Device Interoperability (Contd.)

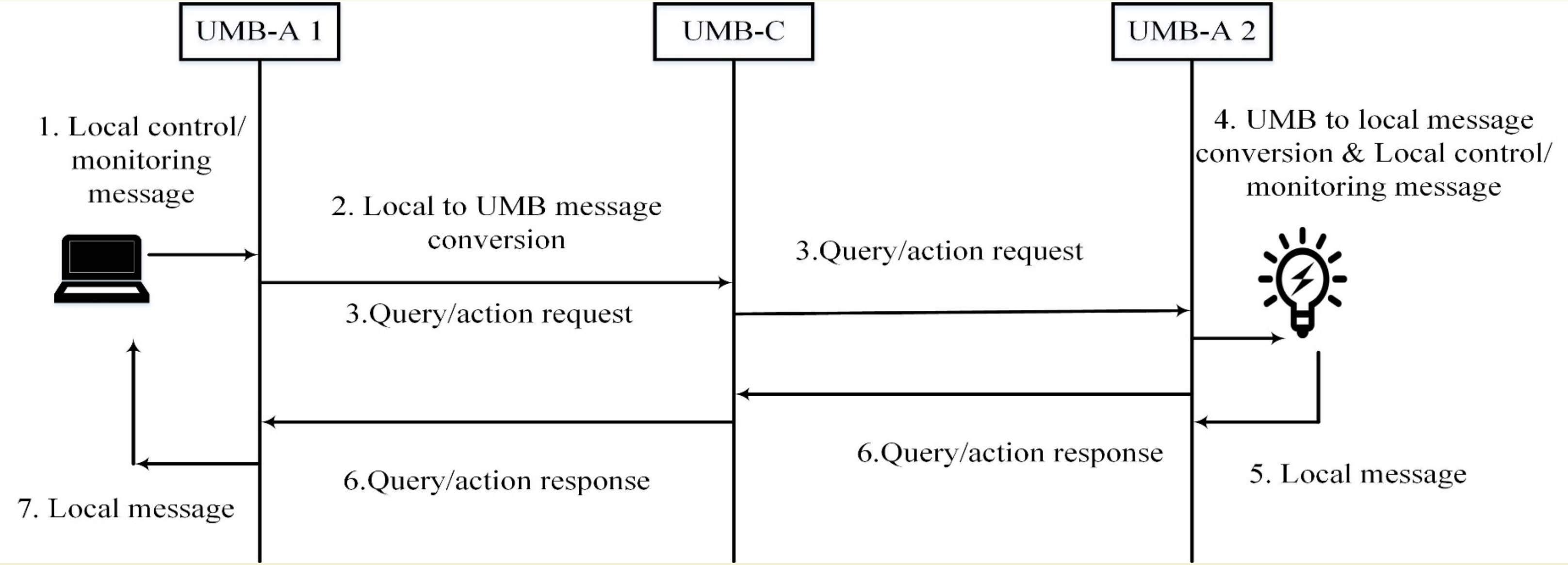

Fig 5: Flow when a device is controlled and monitored

Source: K.-D. Moon, Y.-H. Lee, C.-E. Lee, and Y.-S. Son, “Design of a universal middleware bridge for device interoperability in heterogeneous home network middleware,” IEEE Trans. Consum. Electron., vol. 51, no. 1, pp. 314–318, Feb. 2005.

Thank You!!

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Introduction to Arduino Programming – Part I

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Features of Arduino

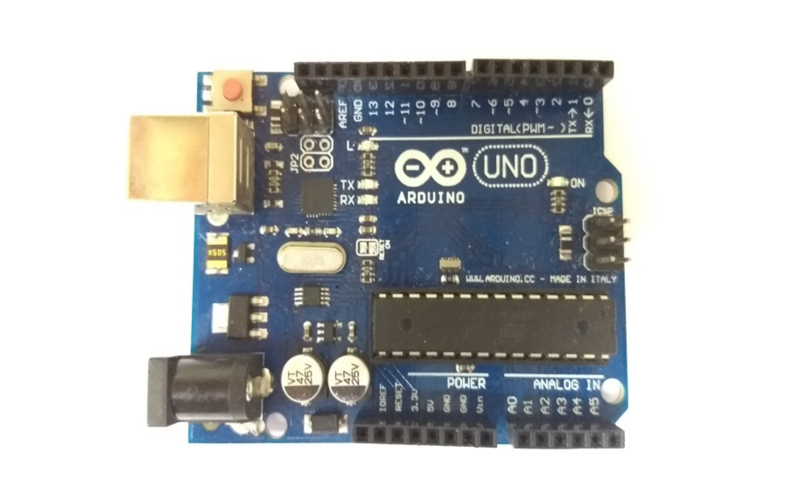
- Open source based electronic programmable board (micro controller)and software(IDE)
- Accepts analog and digital signals as input and gives desired output
- No extra hardware required to load a program into the controller board

Types of Arduino Board

- Arduino boards based on ATMEGA328 microcontroller
- Arduino boards based on ATMEGA32u4 microcontroller
- Arduino boards based on ATMEGA2560 microcontroller
- Arduino boards based on AT91SAM3X8E microcontroller

Arduino UNO

Feature	Value
Operating Voltage	5V
Clock Speed	16MHz
Digital I/O	14
Analog Input	6
PWM	6
UART	1
Interface	USB via ATMega16U2



Board Details

- Power Supply: USB or power barrel jack
- Voltage Regulator
- LED Power Indicator
- Tx-Rx LED Indicator
- Output power, Ground
- Analog Input Pins
- Digital I/O Pins

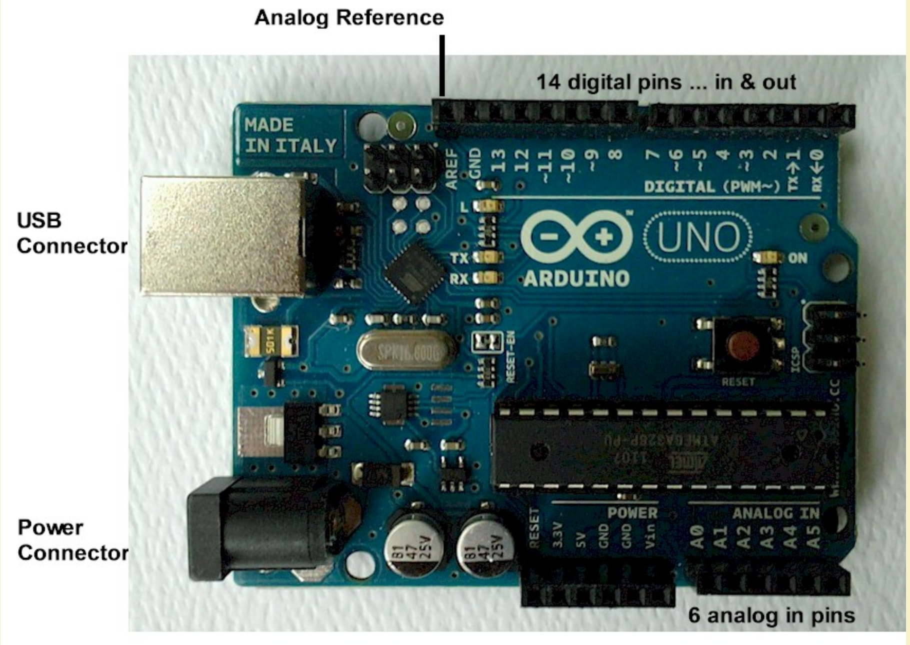


Image source: https://upload.wikimedia.org/wikipedia/commons/9/9d/UnoConnections.jpg

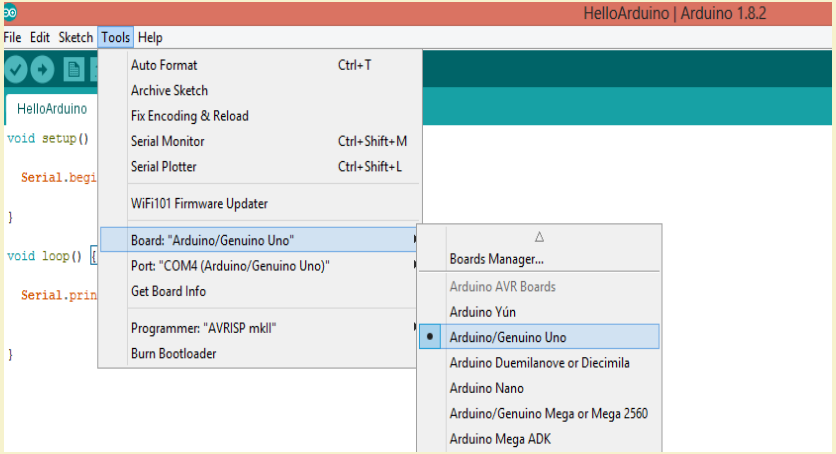
Arduino IDE

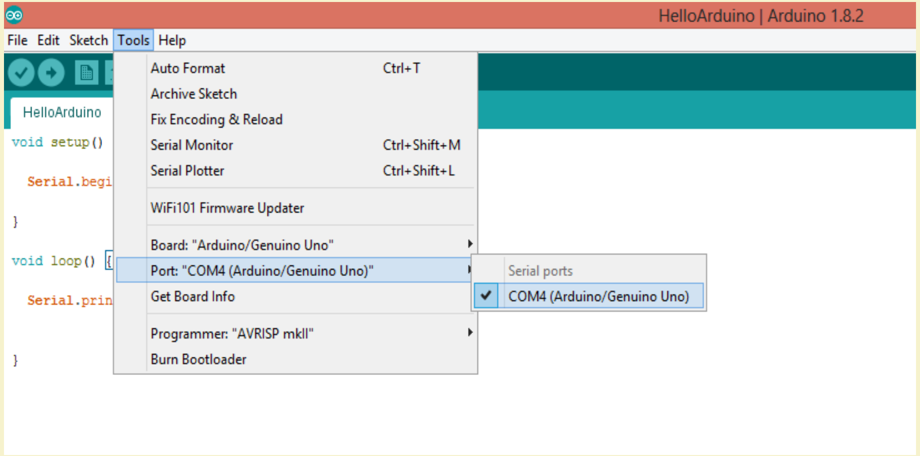
- Arduino IDE is an open source software that is used to program the Arduino controller board
- Based on variations of the C and C++ programming language
- It can be downloaded from Arduino's official website and installed into PC

Set Up

- Power the board by connecting it to a PC via USB cable
- Launch the Arduino IDE
- Set the board type and the port for the board
- TOOLS -> BOARD -> select your board
- TOOLS -> PORT -> select your port

Set up (contd..)


HelloArduino | Arduino 1.8.2
File Edit Sketch Tools Help
HelloArduino
void setup()
Serial.begi
}
void loop() {
Serial.prin
}
Auto Format Ctrl+T
Archive Sketch
Fix Encoding & Reload
Serial Monitor Ctrl+Shift+M
Serial Plotter Ctrl+Shift+L
WiFi101 Firmware Updater
Board: "Arduino/Genuino Uno"
Port: "COM4 (Arduino/Genuino Uno)"
Get Board Info
Programmer: "AVRISP mkII"
Burn Bootloader
Boards Manager...
Arduino AVR Boards
Arduino Yún
Arduino/Genuino Uno
Arduino Duemilanove or Diecimila
Arduino Nano
Arduino/Genuino Mega or Mega 2560
Arduino Mega ADK


HelloArduino | Arduino 1.8.2
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void setup()
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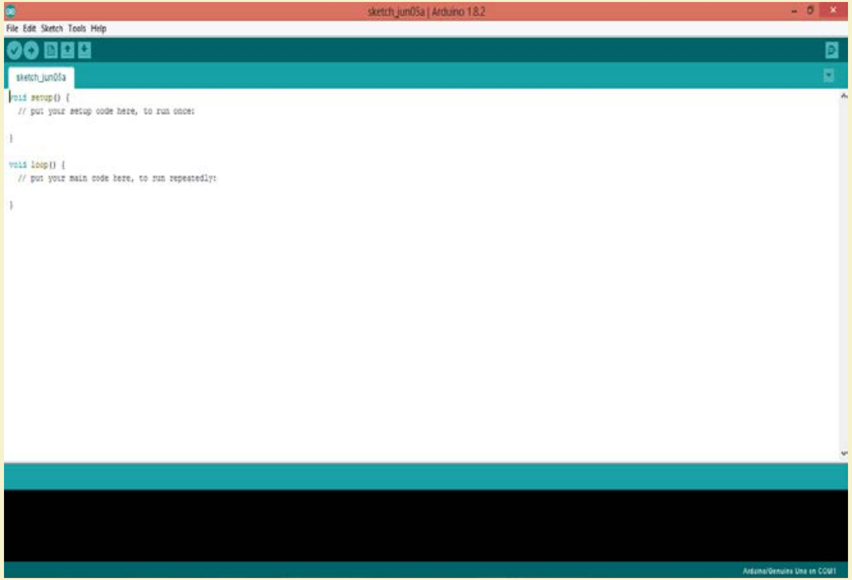
Archive Sketch
Fix Encoding & Reload
Serial Monitor Ctrl+Shift+M
Serial Plotter Ctrl+Shift+L
WiFi101 Firmware Updater
Board: "Arduino/Genuino Uno"
Port: "COM4 (Arduino/Genuino Uno)"
Get Board Info
Programmer: "AVRISP mkII"
Burn Bootloader
Serial ports
COM4 (Arduino/Genuino Uno)

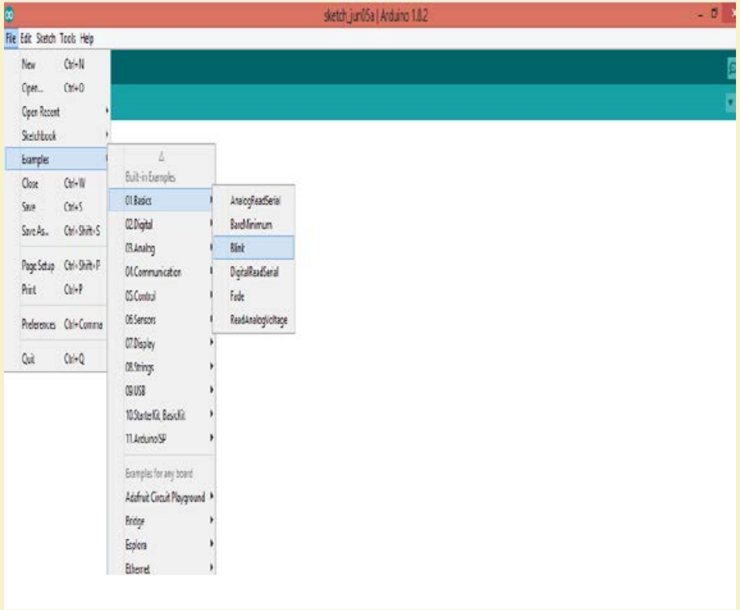
Arduino IDE Overview

Program coded in Arduino IDE is called a SKETCH



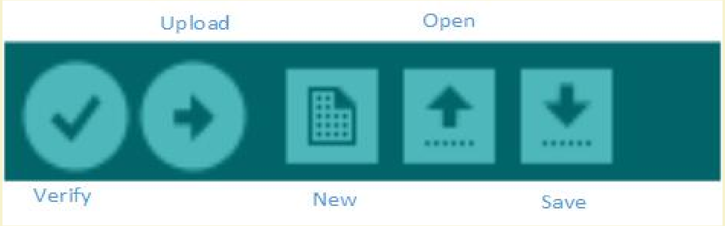
Arduino IDE Overview (contd..)

- To create a new sketch
  - File -> New
- To open an existing sketch
  - File -> open ->
- There are some basic ready-to-use sketches available in the EXAMPLES section
- File -> Examples -> select any program



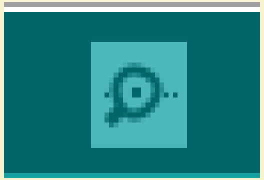
Arduino IDE Overview (contd..)

- Verify: Checks the code for compilation errors
- Upload: Uploads the final code to the controller board
- New: Creates a new blank sketch with basic structure
- Open: Opens an existing sketch
- Save: Saves the current sketch



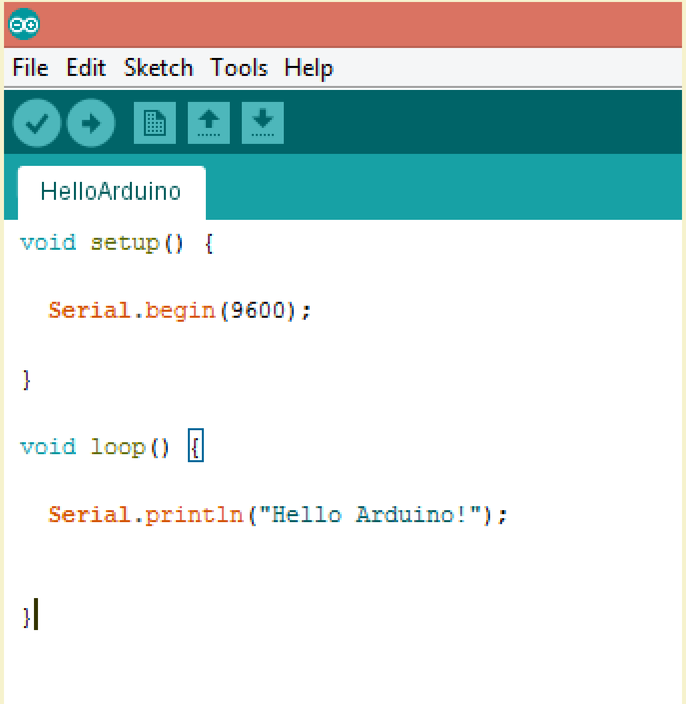
Arduino IDE Overview (contd..)

- Serial Monitor: Opens the serial console
- All the data printed to the console are displayed here



Sketch Structure

- A sketch can be divided into two parts:
  - Setup ()
  - Loop()
- The function setup() is the point where the code starts, just like the main() function in C and C++
- I/O Variables, pin modes are initialized in the Setup() function
- Loop() function, as the name suggests, iterates the specified task in the program



Supported Datatype

- Arduino supports the following data types-

Void	Long
Int	Char
Boolean	Unsigned char
Byte	Unsigned int
Word	Unsigned long
Float	Double
Array	String-char array
String-object	Short

Arduino Function Libraries

- Input/Output Functions:
  - The arduino pins can be configured to act as input or output pins using the pinMode() function

```
Void setup ()
    {
    pinMode (pin , mode);
    }
```

Pin- pin number on the Arduino board

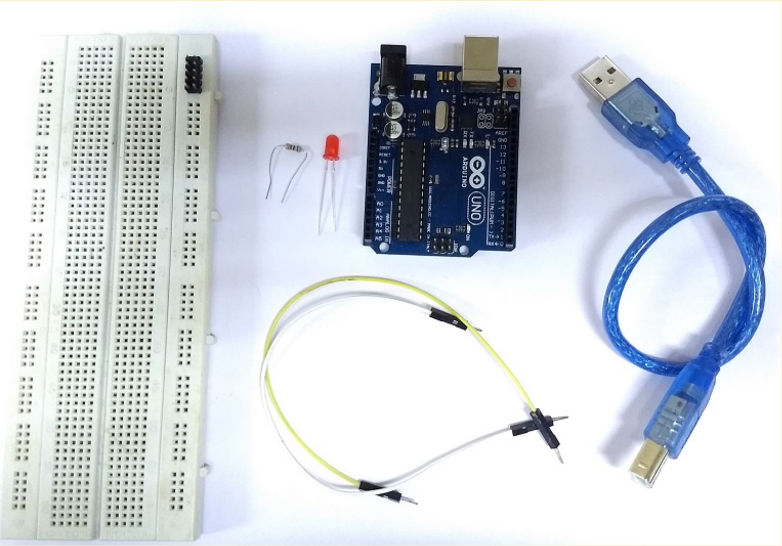
Mode- INPUT/OUTPUT

Arduino Function Libraries (contd..)

- digitalWrite() : Writes a HIGH or LOW value to a digital pin
- analogRead() : Reads from the analog input pin i.e., voltage applied across the pin
- Character functions such as isdigit(), isalpha(), isalnum(), isxdigit(), islower(), isupper(), isspace() return 1(true) or 0(false)
- Delay() function is one of the most common time manipulation function used to provide a delay of specified time. It accepts integer value (time in miliseconds)

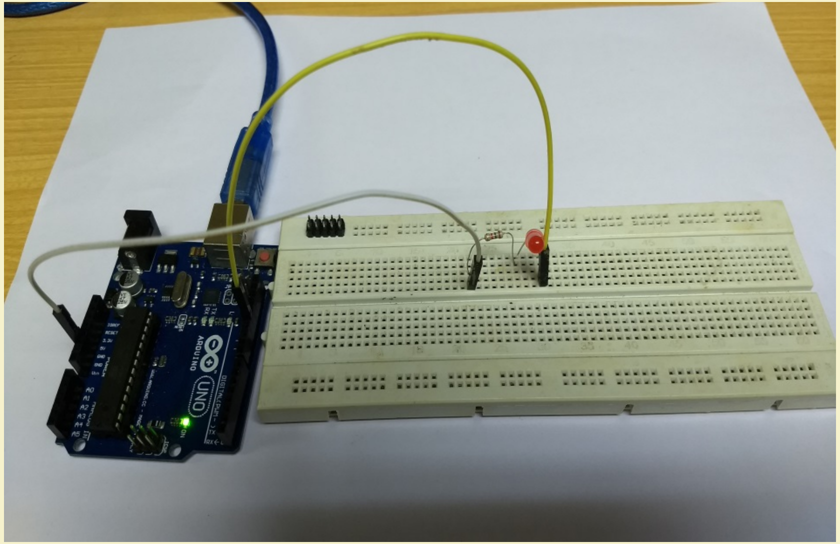
Example- Blinking LED

- Requirement:
  - Arduino controller board, USB connector, Bread board, LED, 1.4Kohm resistor, connecting wires, Arduino IDE
- Connect the LED to the Arduino using the Bread board and the connecting wires
- Connect the Arduino board to the PC using the USB connector
- Select the board type and port
- Write the sketch in the editor, verify and upload.



Example- Blink (contd..)

Connect the positive terminal of the LED to digital pin 12 and the negative terminal to the ground pin (GND) of Arduino Board



Example- Blink (contd..) image setup

```
void setup() {
   pinMode(12, OUTPUT);  // set the pin mode
}
void loop() {
   digitalWrite(12, HIGH);   // Turn on the LED
   delay(1000);
   digitalWrite(12, LOW);  //Turn of the LED
   delay(1000);
}
```

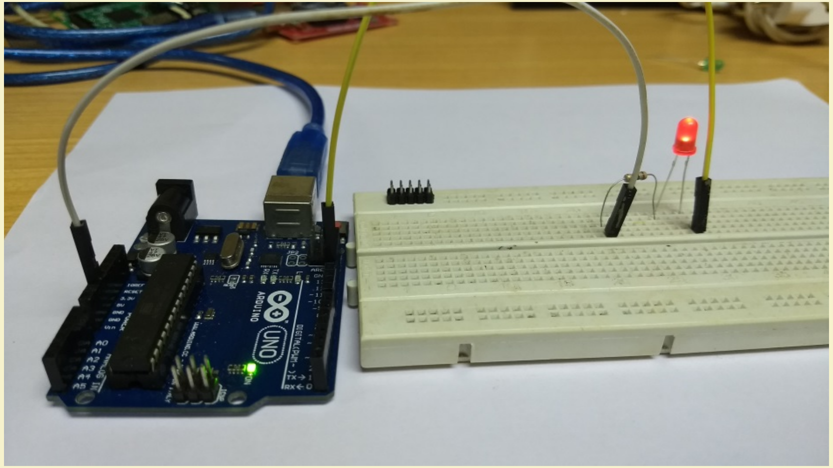
Example- Blink (contd..)

Set the pin mode as output which is connected to the led, pin 12 in this case.

Use digitalWrite() function to set the output as HIGH and LOW

Delay() function is used to specify the delay between HIGH-LOW transition of the output

Example- Blink (contd..) image setup



- Connect he board to the PC
- Set the port and board type
- Verify the code and upload, notice the TX – RX led in the board starts flashing as the code is uploaded.

Thank You!!

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Introduction to Arduino Programming – Part II

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Content

- Operators in Arduino
- Control Statement
- Loops
- Arrays
- String
- Math Library
- Random Number
- Interrupts
- Example Program

Operators

- Arithmetic Operators: =, +, -, *, /, %
- Comparison Operator: ==, !=, <, >, <=, >=
- Boolean Operator: &&, ||, !
- Bitwise Operator: &, |, ^, ~, <<, >>,
- Compound Operator: ++, --, +=, -=, *=, /=, %=, |=, &=

Control Statement

- If statement
  - if(condition){
        Statements if the
        condition is true ;
      }
- If…Else statement
  - if(condition){
      Statements if the
      condition is true;
      }
    else{
      Statements if the
      condition is false;
      }
- If…….Elseif…..Else
  - if (condition1){
      Statements if the
      condition1 is true;
    }
    else if (condition2){
      Statements if the
      condition1 is false
      and condition2 is true;
    }
    else{
      Statements if both the
      conditions are false;
    }

Control Statement (contd..)

- Switch Case
  - Switch(choice)

```
{
case opt1: statement_1;break;
case opt2: statement_2;break;
case opt3: statement_3;break;
.
.
.
case default: statement_default; break;
}
```

- Conditional Operator.
  - Val=(condition)?(Statement1): (Statement2)

Loops

- For loop
  - for(initialization; condition; increment){
      Statement till the condition is true;
    }
- While loop
  - while(condition){
      Statement till the condition is true;
    }
- Do… While loop
  - do{
        Statement till the condition is true;
     }while(condition);

Loops (contd..)

- Nested loop: Calling a loop inside another loop

- Infinite loop: Condition of the loop is always true, the loop will never terminate

Arrays

- Collection of elements having homogenous datatype that are stored in adjacent memory location.
- The conventional starting index is 0.
- Declaration of array:

  <Datatype> array_name[size];

  Ex: int arre[5];

Arrays (contd..)

- Alternative Declaration:

  int arre[]={0,1,2,3,4};

  int arre[5]={0,1,2};

- Multi-dimentional array Declaration:

  <Datatype> array_name[n1] [n2][n3]....;

  Ex: int arre[row][col][height];

String

- Array of characters with NULL as termination is termed as a String.
- Declaration using Array:
  - char str[]="ABCD";
  - char str[4];
    - str[0]='A';
    - str[0]='B';
    - str[0]='C';
    - str[0]=0;
- Declaration using String Object:
  - String str="ABC";

String (contd..)

- Functions of String Object:
  - str.ToUpperCase(): change all the characters of str to upper case
  - str.replace(str1,str2): is str1 is the sub string of str then it will be replaced by str2
  - str.length(): returns the length of the string without considering null

Math Library

- To apply the math functions and mathematical constants, “**MATH.h**” header files is needed to be included.
- Functions:
  - cos(double radian);
  - sin(double radian);
  - tan(double radian);
  - fabs(double val);
  - fmod(double val1, double val2);

Math Library (contd..)

- Functions:
  - exp(double val);
  - log(double val);
  - log10(double val);
  - square(double val);
  - pow(double base, double power);

Random Number

- randomSeed(int v): reset the pseudo-random number generator with seed value v
- random(maxi)=gives a random number within the range [0,maxi]
- random(mini,maxi)=gives a random number within the range [mini,maxi]

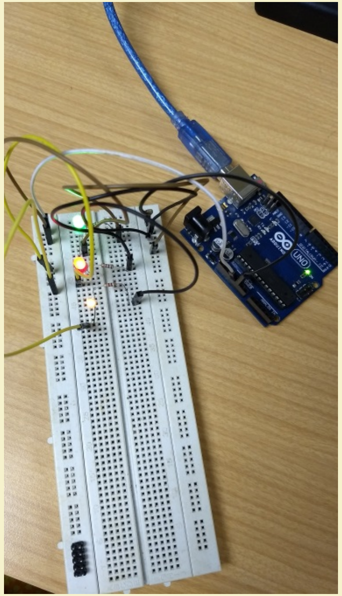
Interrupts

- An external signal for which system blocks the current running process to process that signal
- Types:
  - Hardware interrupt
  - Software interrupt
- digitalPinToInterrupt(pin): Change actual digital pin to the specific interrupt number.
- attachInterrupt(digitalPinToInterrupt(pin), ISR, mode);
  - ISR: a interrupt service routine have to be defined

Example: Traffic Control System

Requirement:

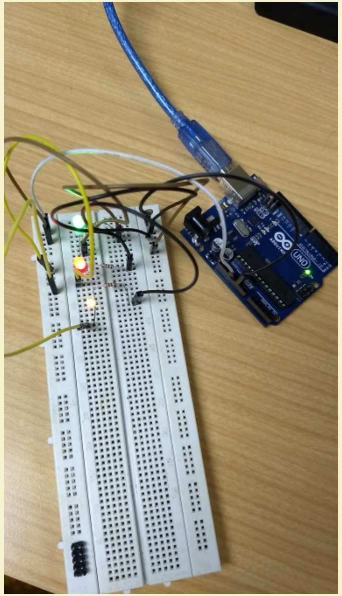
- Arduino Board
- 3 different color LEDs
- 330 Ohm resistors
- Jumper wires



Example: Traffic Control System (contd..)

Connection:

- Connect the positive terminals of the LEDs to the respective digital output pins in the board, assigned in the code.
- Connect the negative terminals of the LEDs to the ground



Example: Traffic Control System (contd..)

- Sketch

```
//LED pins
int r = 2;
int g = 3;
int y = 4;
void setup()
{
       Serial.begin(9600);
       pinMode(r, OUTPUT); digitalWrite(r,LOW);
       pinMode(g, OUTPUT); digitalWrite(g,LOW);
       pinMode(y , OUTPUT); digitalWrite(y, LOW);
}
```

Example: Traffic Control System (contd..)

```
void traffic()
{
    digitalWrite(g, HIGH);
    Serial.println("Green LED: ON, GO");
    // delay of 5 seconds
    delay(5000);
    digitalWrite(g, LOW);
    digitalWrite(y, HIGH);
    Serial.println("Green LED: OFF ; Yellow LED: ON, WAIT");
    delay(5000);
```

Example: Traffic Control System (contd..)

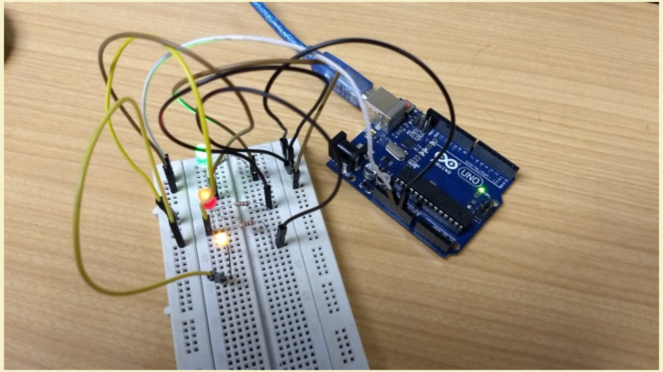
```
        digitalWrite(y, LOW);
        digitalWrite(r, HIGH);
        Serial.println("Yellow LED: OFF ; Red LED: ON, STOP");
        delay(5000);                          // for 5 seconds
        digitalWrite(r, LOW);
        Serial.println("All OFF");
    }

void loop()
{
    traffic ();
    delay (10000);
}
```

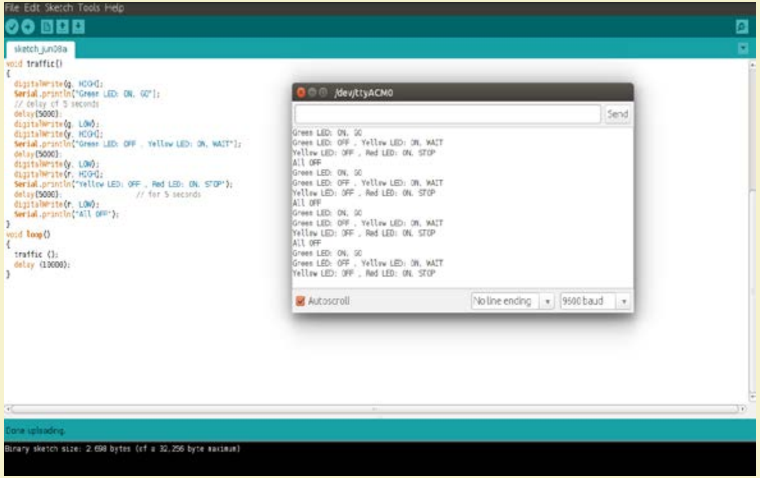
Example: Traffic Control System (contd..)

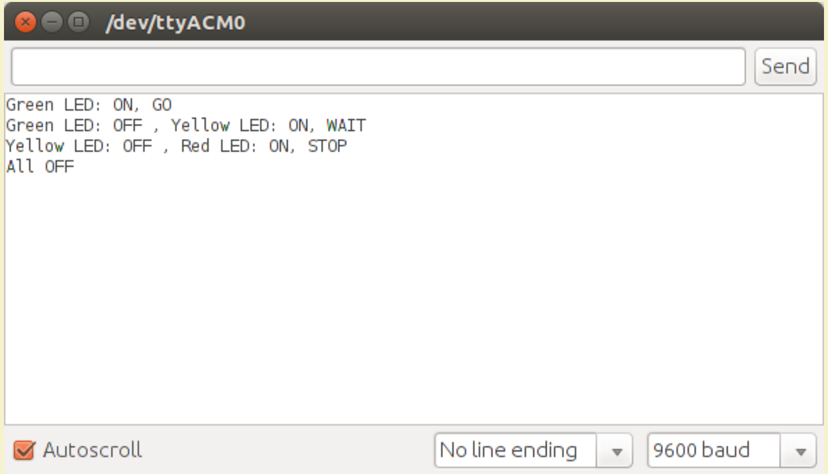
Output:

- Initially, all the LEDs are turned off
- The LEDs are turned on one at a time with a delay of 5 seconds
- The message is displayed accordingly
- Figure showing all the LEDs turned on



Output


File Edit Sketch Tools Help
sketch_jun08a
/dev/ttyACM0
Send
Autoscroll
No line ending
9600 baud
Done uploading.


/dev/ttyACM0
Send
Green LED: ON, GO
Green LED: OFF , Yellow LED: ON, WAIT
Yellow LED: OFF , Red LED: ON, STOP
All OFF
Autoscroll
No line ending
9600 baud

Thank You!!

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Integration of Sensors and Actuators with Arduino- Part I

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Sensors

- Electronic elements
- Converts physical quantity/ measurements into electrical signals
- Can be analog or digital

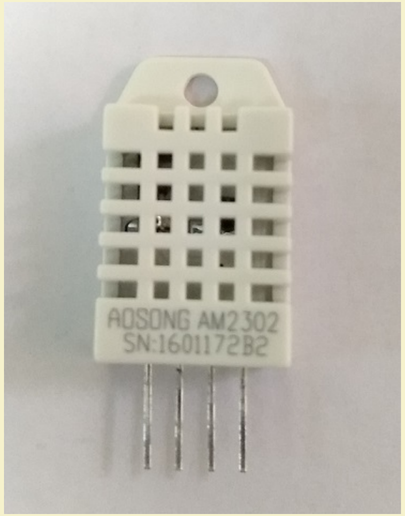
Types of Sensors

Some commonly used sensors:

- Temperature
- Humidity
- Compass
- Light
- Sound
- Accelerometer

Sensor Interface with Arduino

- Digital Humidity and Temperature Sensor (DHT)
- PIN 1, 2, 3, 4 (from left to right)
  - PIN 1- 3.3V-5V Power supply
  - PIN 2- Data
  - PIN 3- Null
  - PIN 4- Ground



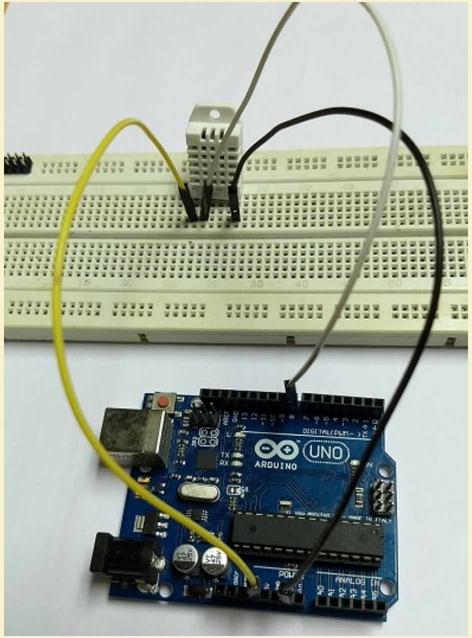
DHT Sensor Library

- Arduino supports a special library for the DHT11 and DHT22 sensors
- Provides function to read the temperature and humidity values from the data pin

```
dht.readHumidity()
dht.readTemperature()
```

Connection

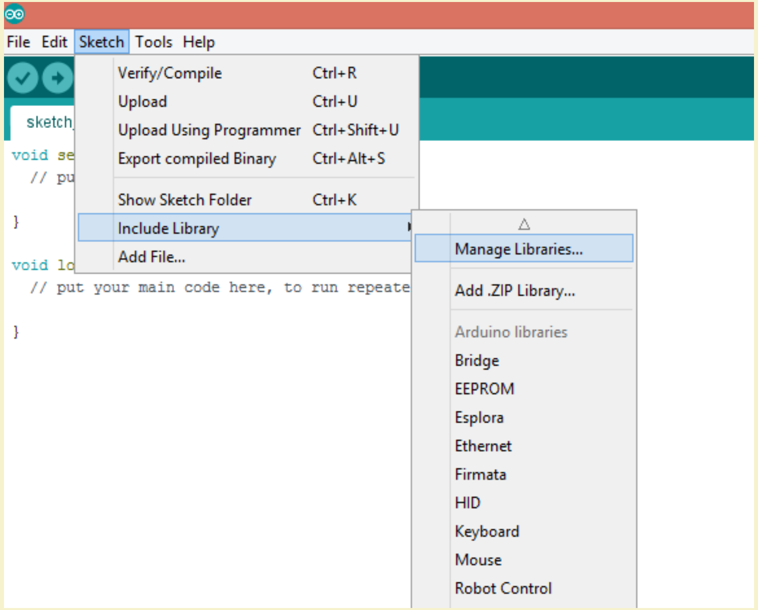
- Connect pin 1 of the DHT to the 3.3 V supply pin in the board
- Data pin (pin 2) can be connected to any digital pin, here 12
- Connect pin 4 to the ground (GND) pin of the board



Sketch: DHT_SENSOR

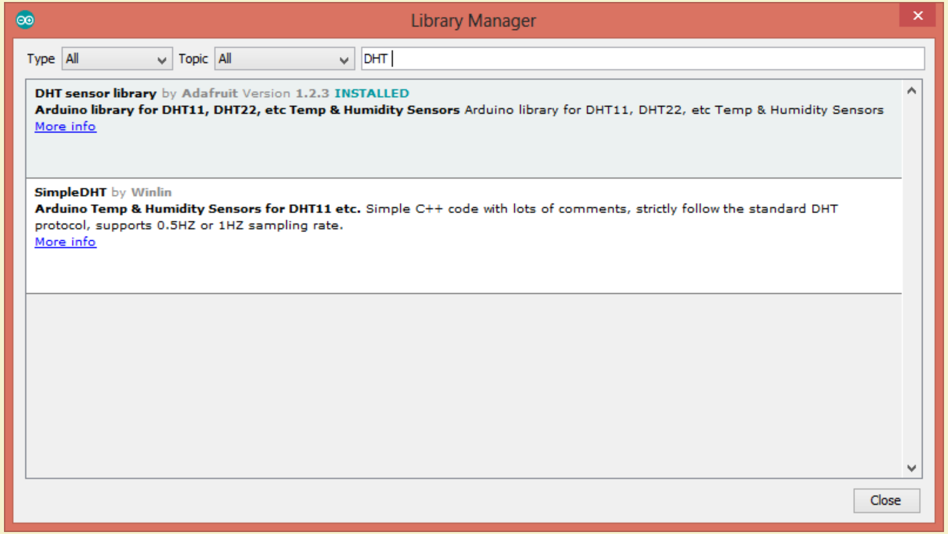
Install the DHT Sensor Library

- Go to Sketch -> Include Library -> Manage Library



Sketch: DHT_SENSOR (contd..)

- Search for DHT SENSOR
- Select the "DHT sensor library" and install it



Sketch: DHT_SENSOR (contd..)

```
#include <DHT.h>;
DHT dht(8, DHT22);      //Initialize DHT sensor
float humidity;         //Stores humidity value
float temperature;      //Stores temperature
value
void setup()
{
  Serial.begin(9600);
  dht.begin();
}
```

```
void loop()
{
   //Read data from the sensor and store it to variables
humidity and temperature
   humidity = dht.readHumidity();
   temperature= dht.readTemperature();
   //Print temperature and humidity values to serial
monitor
   Serial.print("Humidity: ");
   Serial.print(humidity);
   Serial.print("%, Temperature: ");
   Serial.print(temperature);
   Serial.println(" Celsius");
   delay(2000); //Delay of 2 seconds
}
```

Sketch: DHT_SENSOR (contd..)

DHT_SENSOR | Arduino 1.8.2

File Edit Sketch Tools Help

DHT_SENSOR

```
#include <DHT.h>;

//dht() function takes the pin number and the DHT sensor type as parameters, here we are connected at pin 8
DHT dht(8, DHT22); //// Initialize DHT sensor


//Variables
float humidity;  //Stores humidity value
float temperature; //Stores temperature value

void setup()
{
  Serial.begin(9600);
  dht.begin();

}

void loop()
{
    //Read data from the sensor and store it to variables humidity and temperature
    humidity = dht.readHumidity();
    temperature= dht.readTemperature();
    //Print temperature and humidity values to serial monitor
    Serial.print("Humidity: ");
    Serial.print(humidity);
    Serial.print("%, Temperature: ");
    Serial.print(temperature);
    Serial.println(" Celsius");
```

Done Saving.

```
Sketch uses 4966 bytes (15%) of program storage space. Maximum is 32256 bytes.
Global variables use 260 bytes (12%) of dynamic memory, leaving 1788 bytes for local variables. Maximum is 2048 bytes.
```

17

Sketch: DHT_SENSOR (contd..)

- Connect the board to the PC
- Set the port and board type
- Verify and upload the code

Output

The readings are printed at a delay of 2 seconds as specified by the delay() function

```
Humidity: 65.80%, Temperature: 26.00 Celsius
Humidity: 65.80%, Temperature: 26.00 Celsius
Humidity: 65.80%, Temperature: 26.00 Celsius
Humidity: 65.80%, Temperature: 26.00 Celsius
Humidity: 65.80%, Temperature: 26.00 Celsius
Humidity: 65.80%, Temperature: 26.00 Celsius
Humidity: 65.80%, Temperature: 26.00 Celsius
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Humidity: 65.80%, Temperature: 26.00 Celsius
Humidity: 65.80%, Temperature: 26.00 Celsius
Humidity: 65.80%, Temperature: 26.00 Celsius
Humidity: 65.80%, Temperature: 26.00 Celsius
Humidity: 65.80%, Temperature: 26.00 Celsius
```

Thank You!!

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Integration of Sensors and Actuators with Arduino- Part II

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Topics Covered

- Introduction to ACTUATOR
- Servo Motor
- Servo motor interfaced with Arduino
  - Hardware interface
  - Sketch

Actuators

- Mechanical/Electro-mechanical device
- Converts energy into motion
- Mainly used to provide controlled motion to other components

Basic Working Principle

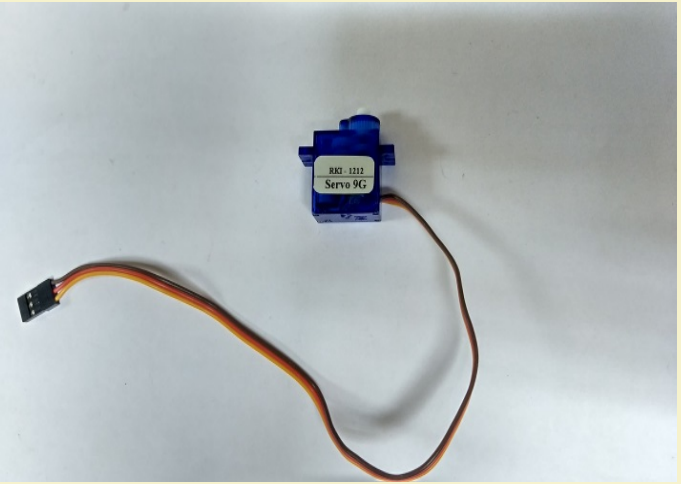
Uses different combination of various mechanical structures like screws, ball bearings, gears to produce motion.

Types of Motor Actuators

- Servo motor
- Stepper motor
- Hydraulic motor
- Solenoid
- Relay
- AC motor

Servo Motor

- High precision motor
- Provides rotary motion 0 to 180 degree
- 3 wires in the Servo motor
  - Black or the darkest one is Ground
  - Red is for power supply
  - Yellow for signal pin



Servo Library on Arduino

- Arduino provides different library- SERVO to operate the servo motor
- Create an instance of servo to use it in the sketch

Servo myservo;

Sketch: SERVO_ACTUATOR

```
#include <Servo.h>
//Including the servo library for the program
int servoPin = 12;


Servo ServoDemo; // Creating a servo object
void setup() {
  // The servo pin must be attached to the servo
before it can be used
  ServoDemo.attach(servoPin);
}
```

```
void loop(){
  //Servo moves to 0 degrees
   ServoDemo.write(0);
   delay(1000);

  // Servo moves to 90 degrees
   ServoDemo.write(90);
   delay(1000);

  // Servo moves to 180 degrees
   ServoDemo.write(180);
   delay(1000);
}
```

Sketch: SERVO_ACTUATOR (contd..)

- Create an instance of Servo
- The instance must be attached to the pin before being used in the code
- Write() function takes the degree value and rotates the motor accordingly

File Edit Sketch Tools Help

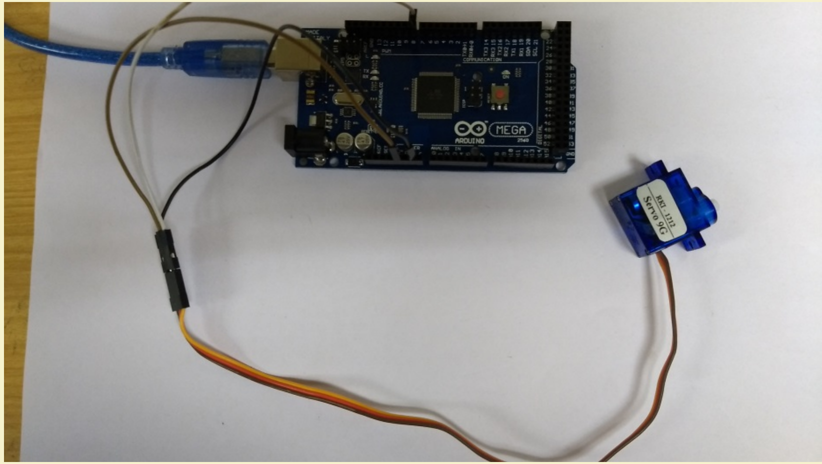
SERVO_ACTUATOR

```
#include <Servo.h> //Including the servo library for the program
int servoPin = 8;

Servo ServoDemo; // Creating a servo object
void setup() {
  // The servo pin must be attached to the servo before it can be used
  ServoDemo.attach(servoPin);
}
void loop(){
  //Servo moves to 0 degrees
  ServoDemo.write(0);
  delay(1000);
  // Servo moves to 90 degrees
  ServoDemo.write(90);
  delay(1000);
  // Servo moves to 180 degrees
  ServoDemo.write(180);
  delay(1000);
}
```

Connection

- Connect the Ground of the servo to the ground of the Arduino board.
- Connect the power supply wire to the 5V pin of the board.
- Connect the signal wire to any digital output pin (we have used pin 8).

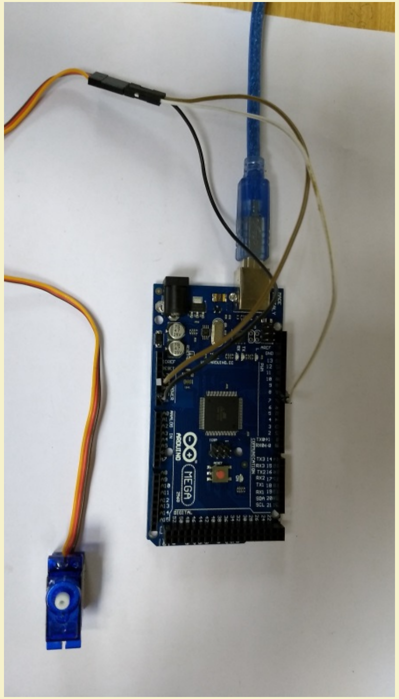


Board Setup

- Connect the board to the PC
- Set the port and board type
- Verify and upload the code

Output

The motor turns 0, 90 and 180 degrees with a delay of 1 second each.



Do more with the Servo library

Some other functions available with the Servo library:

- Knob()
- Sweep()
- write()
- writeMicroseconds()
- read()
- attached()
- detach()

Source: "Servo Library", Arduino Home (Online), Link: www.arduino.cc/en/Reference/Servo

Thank You!!