An Inexpensive Autonomous Mobile Robot for Undergraduate Education: Integration of Arduino and Hokuyo Laser Range Finders

Course Material

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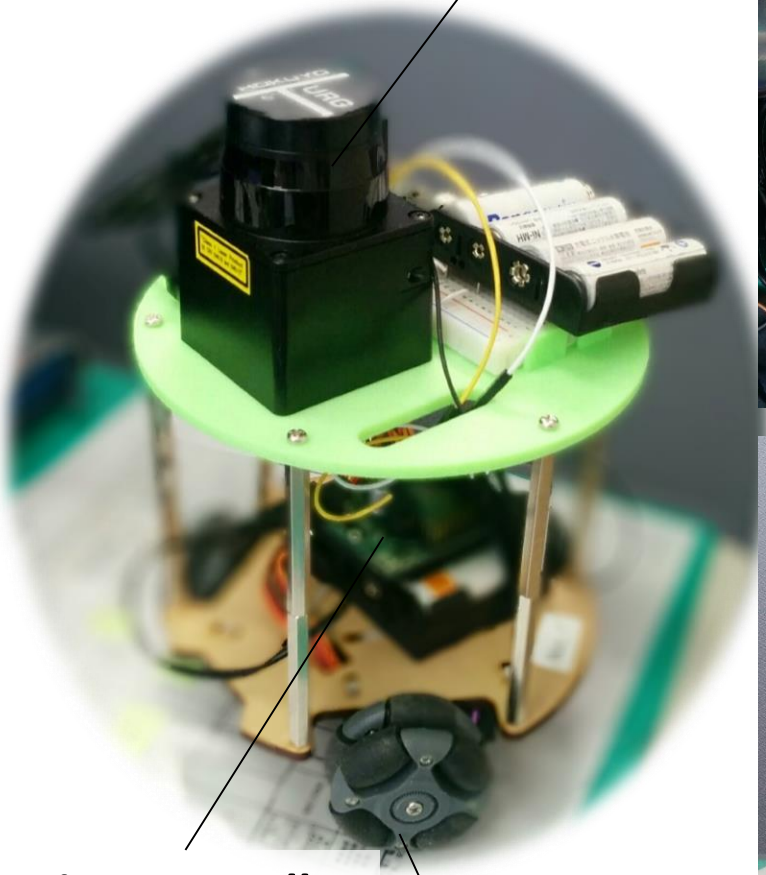
Course plan

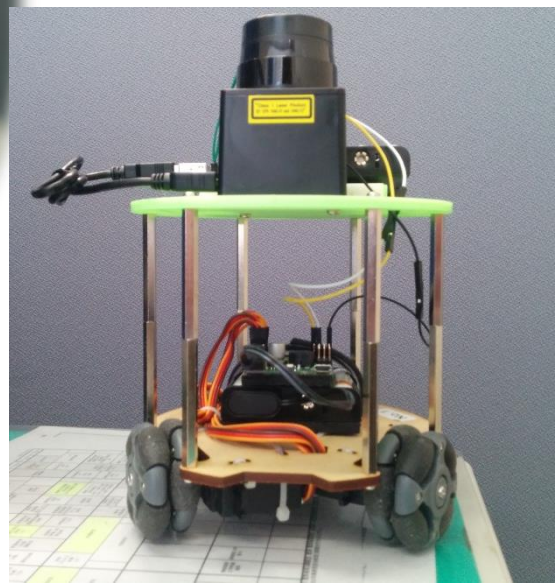
Week	Learning contents
1	Introduction
2～3	Programming basis
4	Feedback control using LRF
5～8	Project work
9	Preparing presentation
10	Presentation

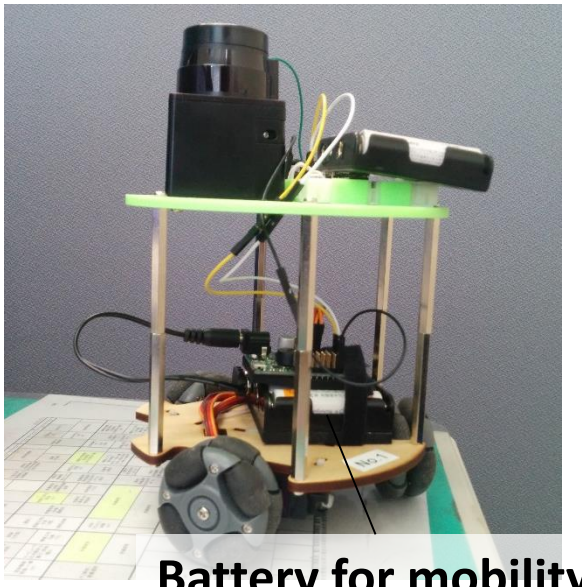
Autonomous mobile vehicle

LiDAR (Light detection and ranging)
LRF (Laser range-finder)

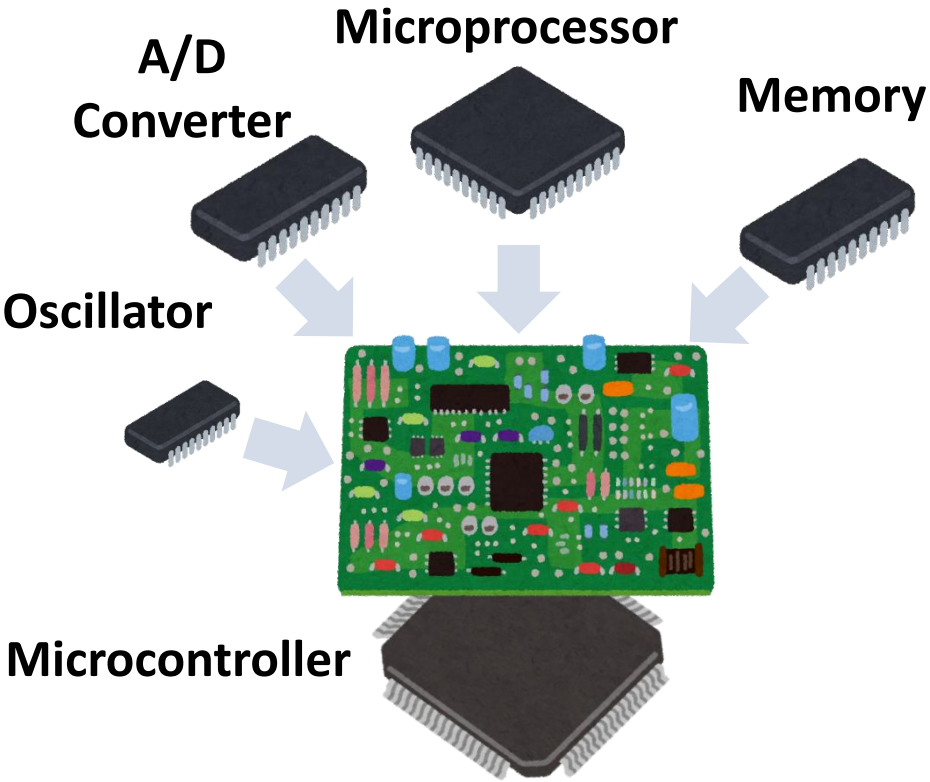
Robot used in this course







Microcontroller

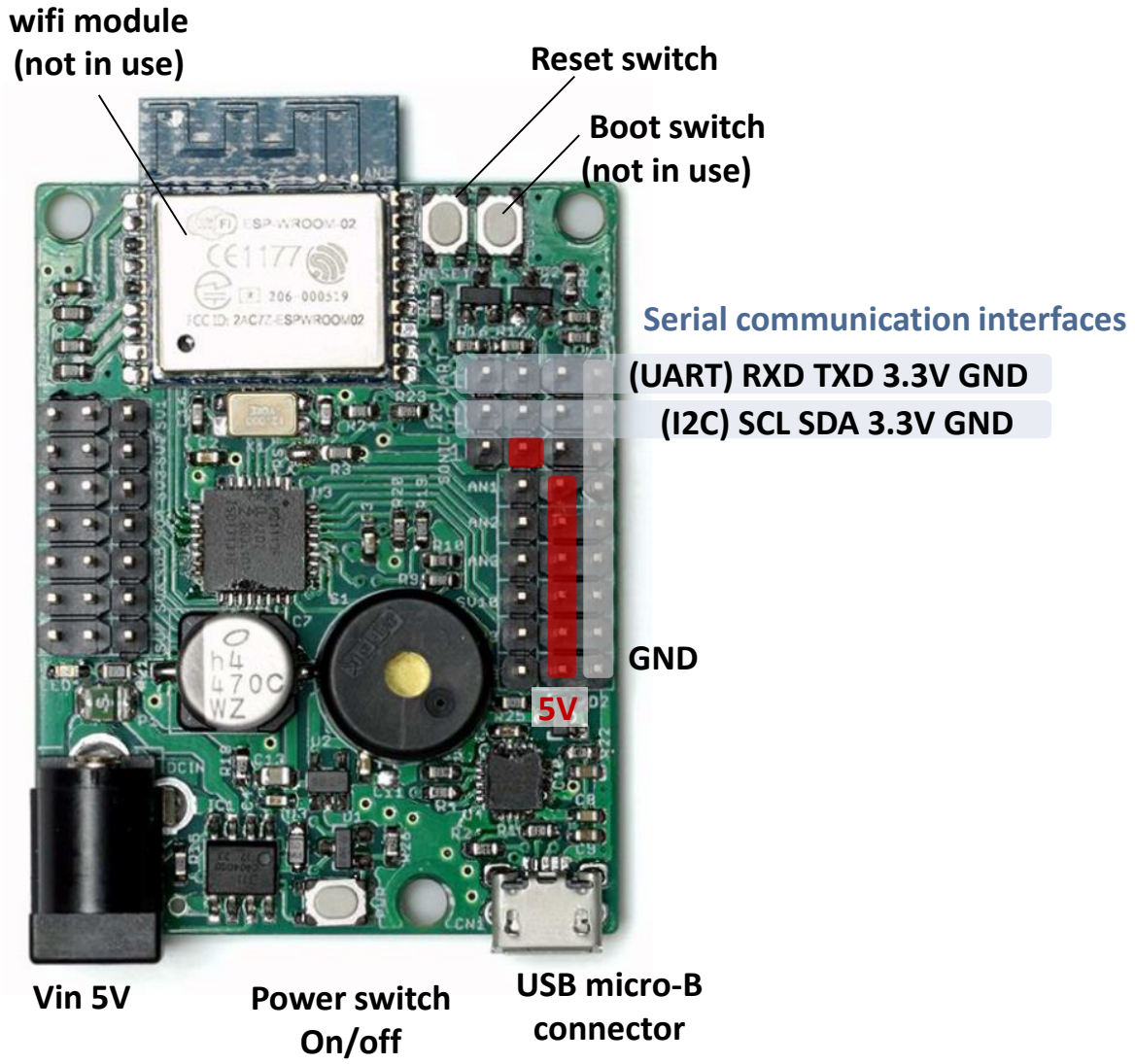


- Small computer integrated into an IC chip.
  - Processor, Memory, I/O
- Comact & low-cost.
- Embedded in appliances.

Arduino boards:

- Arduino is a family of single-board microcontrollers as open-source design.
- Easy to use for development and prototyping.

v-duino board (Compatible with Arduino)



Embedded programming

- Variable
- Conditional statements (IF, ELSE)
- Loop iteration (FOR, WHILE)
- Function
- Arrays
- Servo motor
- Serial communication

Arduino program (sketch) structure

SerialTest0 | Arduino 1.8.8

ファイル 編集 スケッチ ツール ヘルプ

SerialTest0 §

```
#include <vs-rc202.h>

void setup() {
  initLib();                  //Initilize vs-rc202 library
  servoEnable(1, 1);          //Enable SV1 PWM
  setServoMovingTime(1000); //Set moving time to the target position
  Serial.begin(115200);     // 115200bpsでシリアルポートを開く
}

void loop() {
  setServoDeg(1, 0);          //Set SV1 servo target position
  moveServo();                //Start to move servo
  delay(1200);
  setServoDeg(1, 500);
  moveServo();
  delay(1200);
  /* シリアルモニタ
    に表示*/
  Serial.println("Hello World!");
}
```

Comments (not executed)

Comments (not executed)

d26cu, 26 MHz, 40MHz, DIO, 2M (1M SPIFFS), 2, v2 Lower Memory, Disabled, None, Only Sketch, 115200

Library (header file)

- **Loads a set of functions for control motors.**

setup() function

- **Called when a sketch starts.**

loop() function

- **Loops consecutively, after executing a setup() function.**

COM6

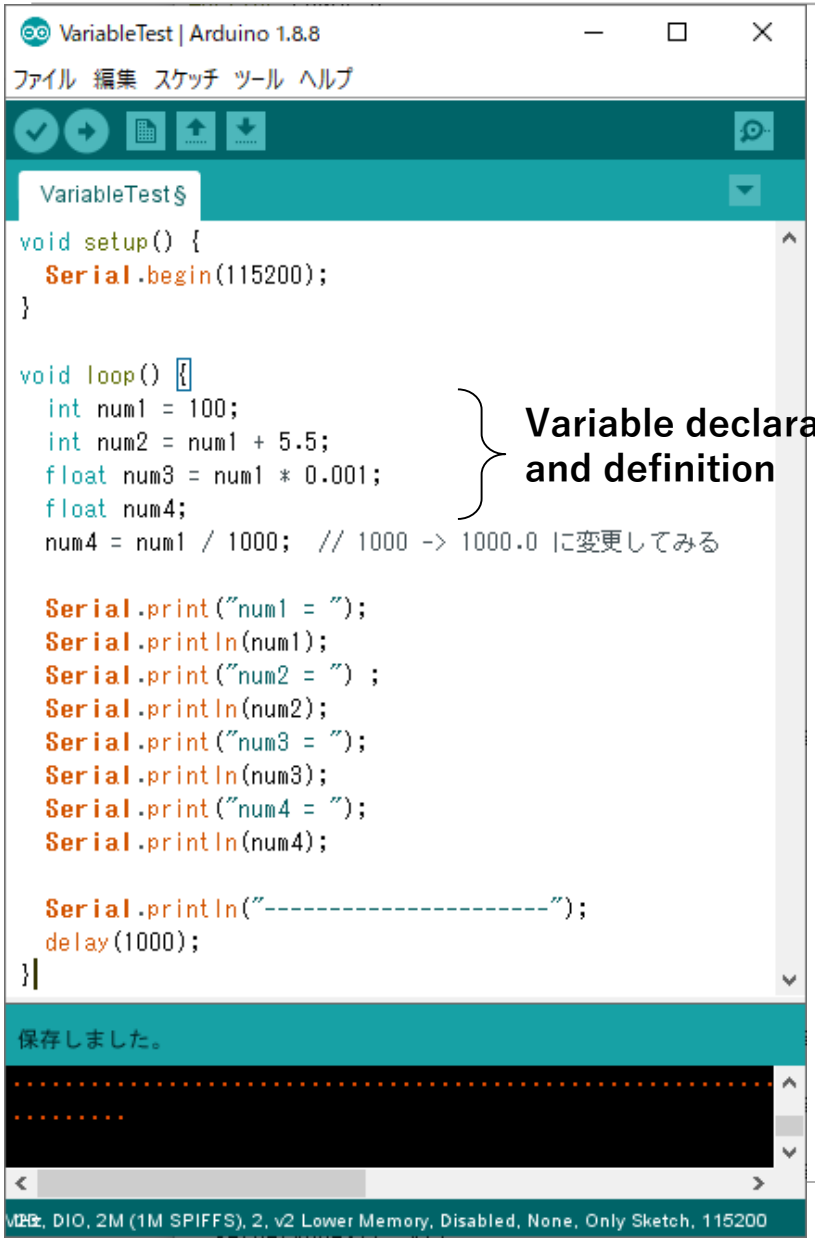
送信

```
Hello World!
Hello World!
Hello World!
Hello World!
Hello World!
```

Serial monitor (Outputs of the sketch)

自動スクロール タイムスタンプを表示 CRおよびL... 115200 bps 出力をクリア

Variable



Variable declaration and definition

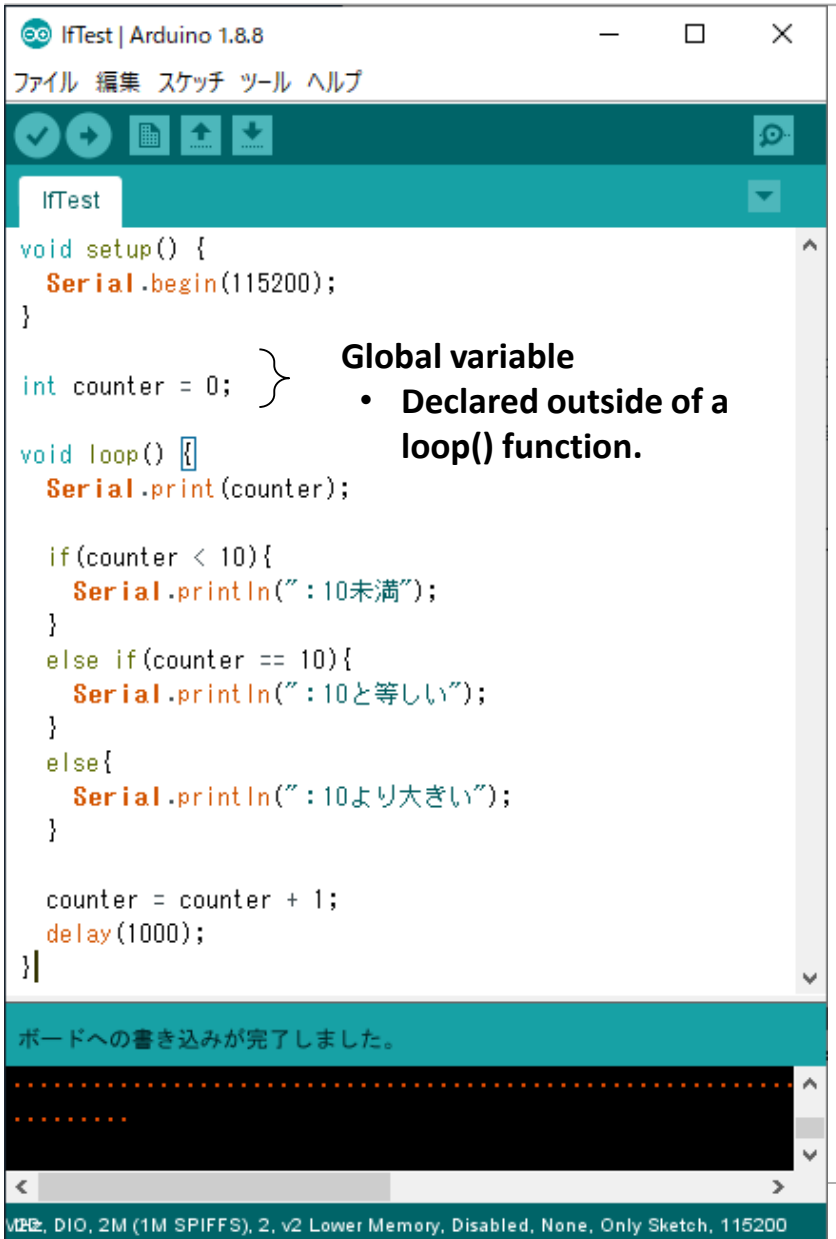
int num1 = 100;

Type **Variable's name** **Value (Not necessary for the declaration)**

Type	Description
void	Represents the absence of type.
char	A single octet (one byte).
int	Integer value.
float	Floating point value.

- **A variable is a storage location paired with an associated symbolic name.**
- **Required to choose a type of variable according to data.**

IF/ELSE 1/2



Global variable

- **Declared outside of a loop() function.**

```
if (condition A) {
        // Do stuff if the condition A is true.
}
else if (condition B){
        // Do stuff only if the condition A is false,
        // and the condition B is true.
}
else {
        // Do stuff if both of the conditions A and B are false.
}
```

Multiple conditions :

(and)

```
if (condition A && condition B) {
        // Do stuff if both of the conditions A and B are true.
}
```

(or)

```
if (condition A || condition B) {
        // Do stuff
        // if at lease one of the conditions A and B is true.
}
```

IF, ELSE 2/2

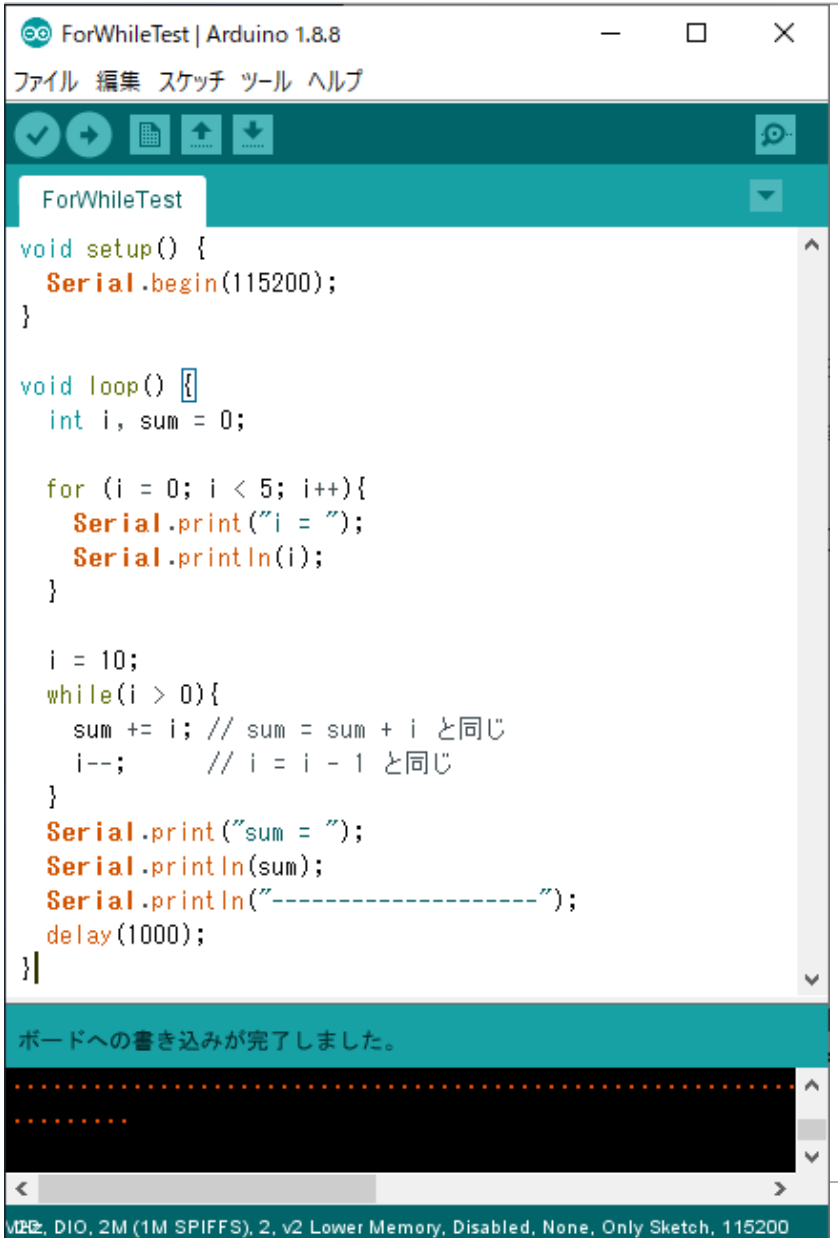
Conditional expressions :

Exp	Description
A == B	Equal A to B.
A != B	Not equal A to B.
A < B	A is less than B.
A > B	A is grater than B.
A <= B	A is less than or equal to B.
A >= B	A is greater than or equal to B.

Switch case :

```
switch (variable) {
        case value1 :
                // Do stuff if variable = value1
                break;
        case value2 :
                // Do stuff if variable = value2
                break;
        case value3 :
                // Do stuff if variable = value3
                break;
                .
                .
                .
        default :
                // Do stuff if there is no match above cases
}
```

FOR, WHILE



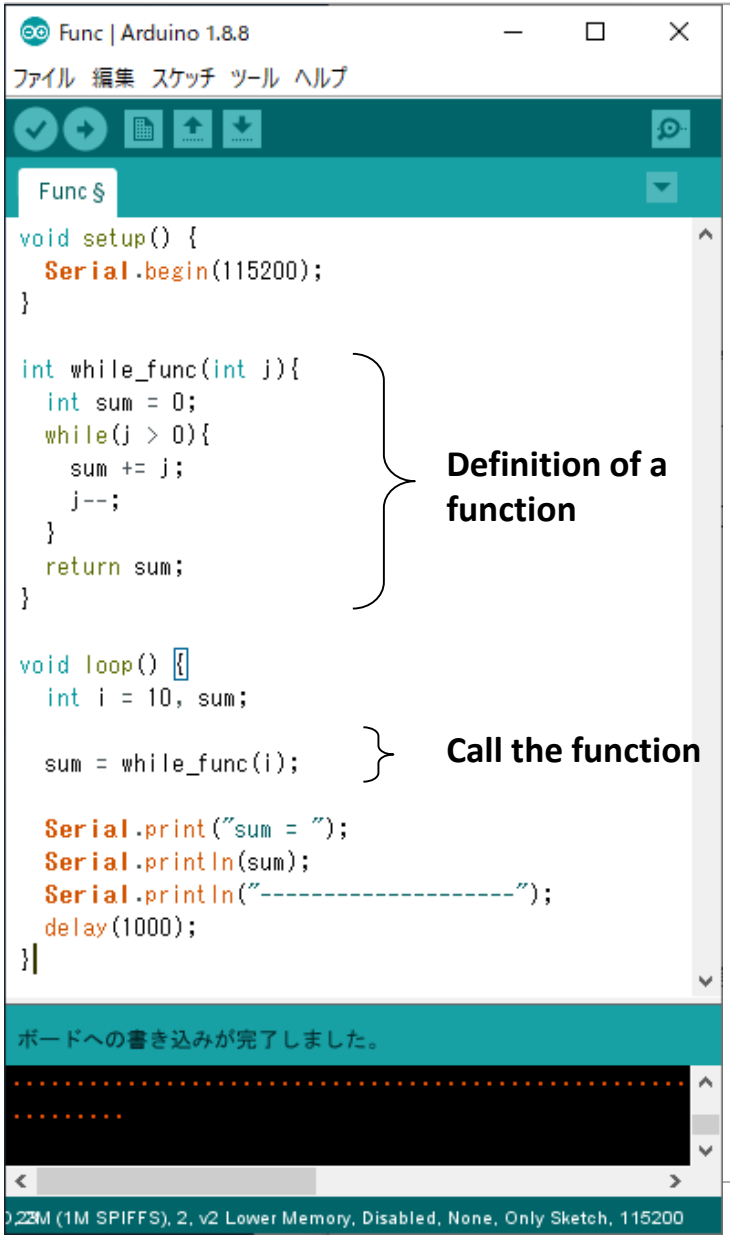
for loop :

```
for (initialization; condition ; increment) {
        // Do stuff repeatedly for the condition is true.
        .
        .
        .
}
```

while loop :

```
while (condition A) {
        // Do stuff repeatedly while the condition A is true.
        .
        .
        .
}
```

Function



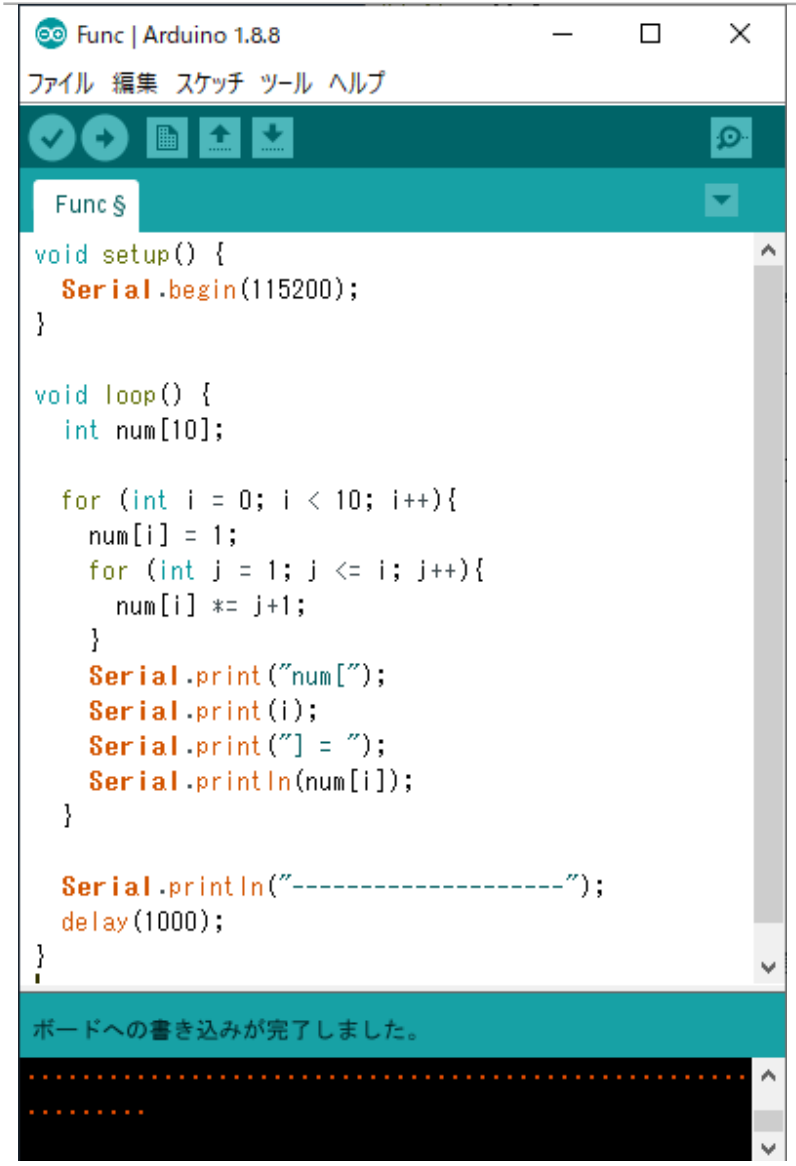
Function with return value :

```
Return-type function (argment1, argment2, …) {
        // statements
        .
        .
        .
        return value;
}
```

Function without return value :

```
void function (argment1, argment2 , …) {
        // statements
        .
        .
        .
}
```

Arrays




```
int num[3] = {1, 2, 3};
```

Type **Array name[size]** **Initial values**
(Required unique name) **(Not necessary for declaration)**

num[0]	num[1]	num[2]
1	2	3

If the size of the array is 3, the array is start from index 0 as num[0] to last to index 2 as num[2].

Two-dimensional array :

```
int num[2][2] = {{1, 2}, {3, 4}};
```

num[0][0]	1	2 num[0][1]
num[1][0]	3	4 num[1][1]

Servo motor using serial comm

SerialTest | Arduino 1.8.8

ファイル 編集 スケッチ ツール ヘルプ

SerialTest§

```
#include <vs-rc202.h>

void setup() {
  initLib();                //Initilize vs-rc202 library
  servoEnable(1, 1);        //Enable SV1 PWM
  setServoMovingTime(1000); //Set moving time to the target posit
  Serial.begin(115200);      // 115200bpsでシリアルポートを開く
}

int spd = 0;

void loop() {
  char sgn;       // + or -

  if(Serial.available() > 0){ // 受信したデータが存在する
    sgn = Serial.read();

    if (sgn == '+'){  // 入力された文字が+のとき
      spd = spd + 100;
    } else if(sgn == '-'){ // 入力された文字が-のとき
      spd = spd - 100;
    }
  }

  setServoDeg(1, spd);      //回転速度をspdに設定
  moveServo();
  delay(1200);

  Serial.print("回転速度:");  // 受信データを表示
  Serial.println(spd);
}
```

80MHz, 40MHz, DIO, 2M (1M SPIFFS), 2, v2 Lower Memory, Disabled, None, Only Sketch, 115200

Press 'Enter' after input '+' or '-'.

COM6

+

送信

回転速度:0
回転速度:100
回転速度:100
回転速度:100
回転速度:100
回転速度:100
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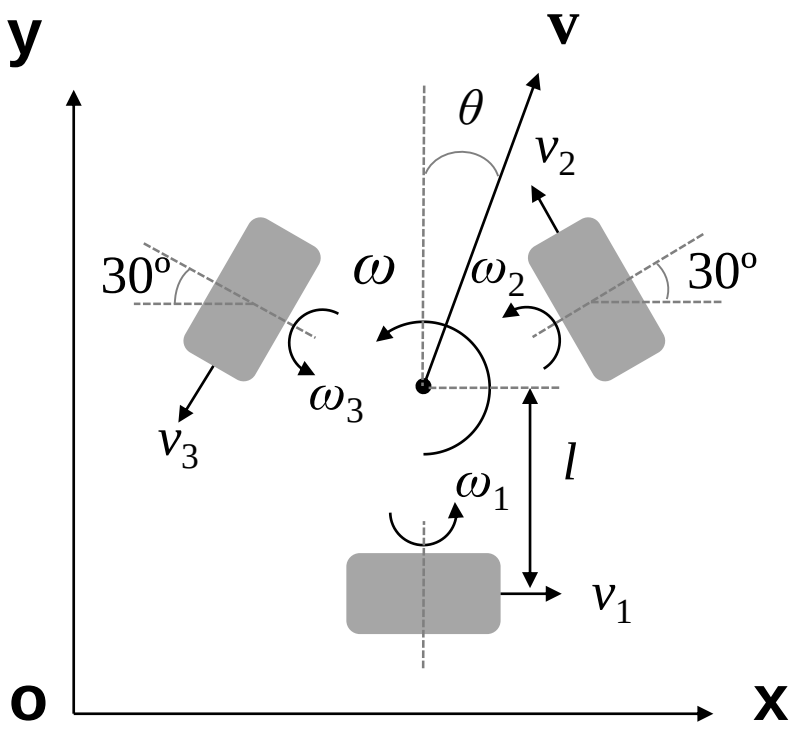
回転速度:0

自動スクロール　タイムスタンプを表示　CRおよびL...　115200 bps　出力をクリア

Kinematics of the mobile robot 1/2



Velocity in the body coordinates :

$$\mathbf{v} = \begin{bmatrix} v_x \\ v_y \end{bmatrix} = \begin{bmatrix} v\sin\theta \\ v\cos\theta \end{bmatrix}$$

Velocity of the wheels :

$$\begin{bmatrix} v_1 \\ v_2 \\ v_3 \end{bmatrix} = \begin{bmatrix} r\omega_1 \\ r\omega_2 \\ r\omega_3 \end{bmatrix} = \begin{bmatrix} 1 & 0 & l \\ -\sin 30^\circ & \cos 30^\circ & l \\ -\sin 30^\circ & -\cos 30^\circ & l \end{bmatrix} \begin{bmatrix} v_x \\ v_y \\ \omega \end{bmatrix}$$

r : **Radius of the wheel**

Kinematics of the mobile robot 2/2

Relationship between the world and body coordinates :

$$\begin{bmatrix} v_x \\ v_y \end{bmatrix} = \begin{bmatrix} \cos\phi & \sin\phi \\ -\sin\phi & \cos\phi \end{bmatrix} \begin{bmatrix} v_x^w \\ v_y^w \end{bmatrix}$$

ϕ : **Heading direction of the robot**

Velocity in the body coordinates

Velocity in the world coordinates

Velocity of the wheels :

$$\begin{bmatrix} v_1 \\ v_2 \\ v_3 \end{bmatrix} = \begin{bmatrix} 1 & 0 & l \\ -\sin 30^\circ & \cos 30^\circ & l \\ -\sin 30^\circ & -\cos 30^\circ & l \end{bmatrix} \begin{bmatrix} \cos\phi & \sin\phi & 0 \\ -\sin\phi & \cos\phi & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} v_x^w \\ v_y^w \\ \omega \end{bmatrix}$$

$$= \begin{bmatrix} \cos\phi & \cos\phi & l \\ -\sin(\phi+30^\circ) & \cos(\phi+30^\circ) & l \\ \sin(\phi-30^\circ) & -\cos(\phi-30^\circ) & l \end{bmatrix} \begin{bmatrix} v_x^w \\ v_y^w \\ \omega \end{bmatrix}$$

where

$$\phi = \int \omega \, dt$$

Feedforward control

- **Make a sketch to circle around an obstacle.**

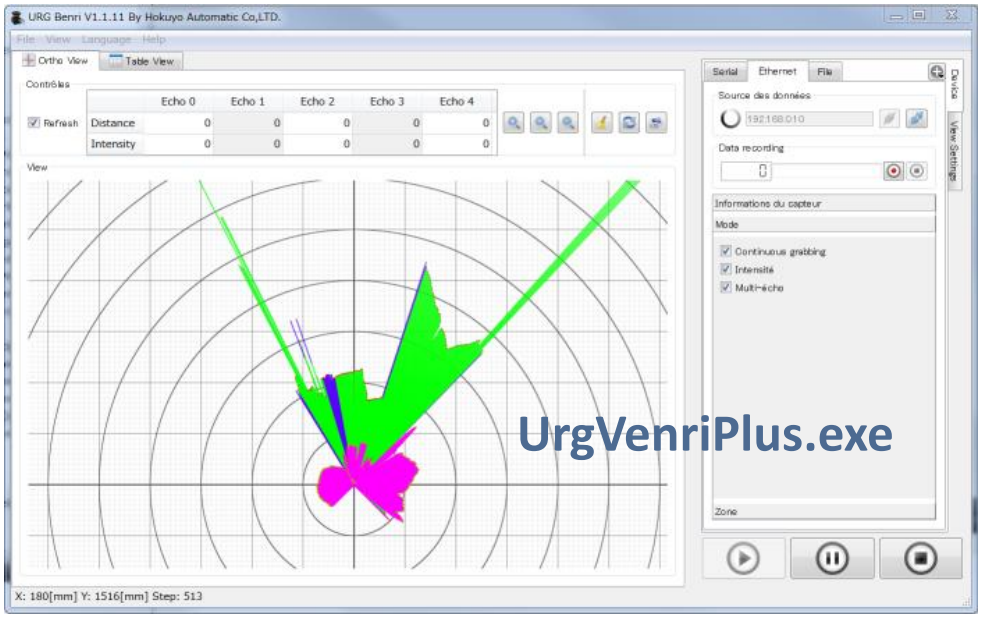
Feedback control using LRF

- Operation verification of Hokuyo LRF
- How to use breadboards
- Connect the LRF to Arduino
- Control the robot using the LRF

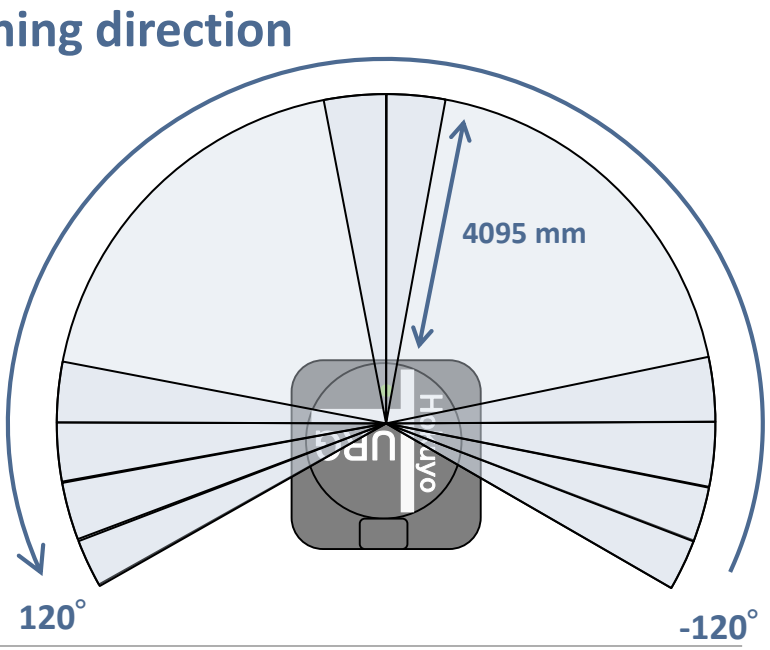
Hokuyo LRF

URG-04LX-UG01 (Hokuyo automatic)

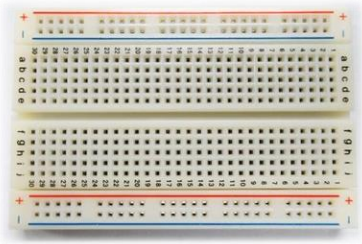
Operation verification :

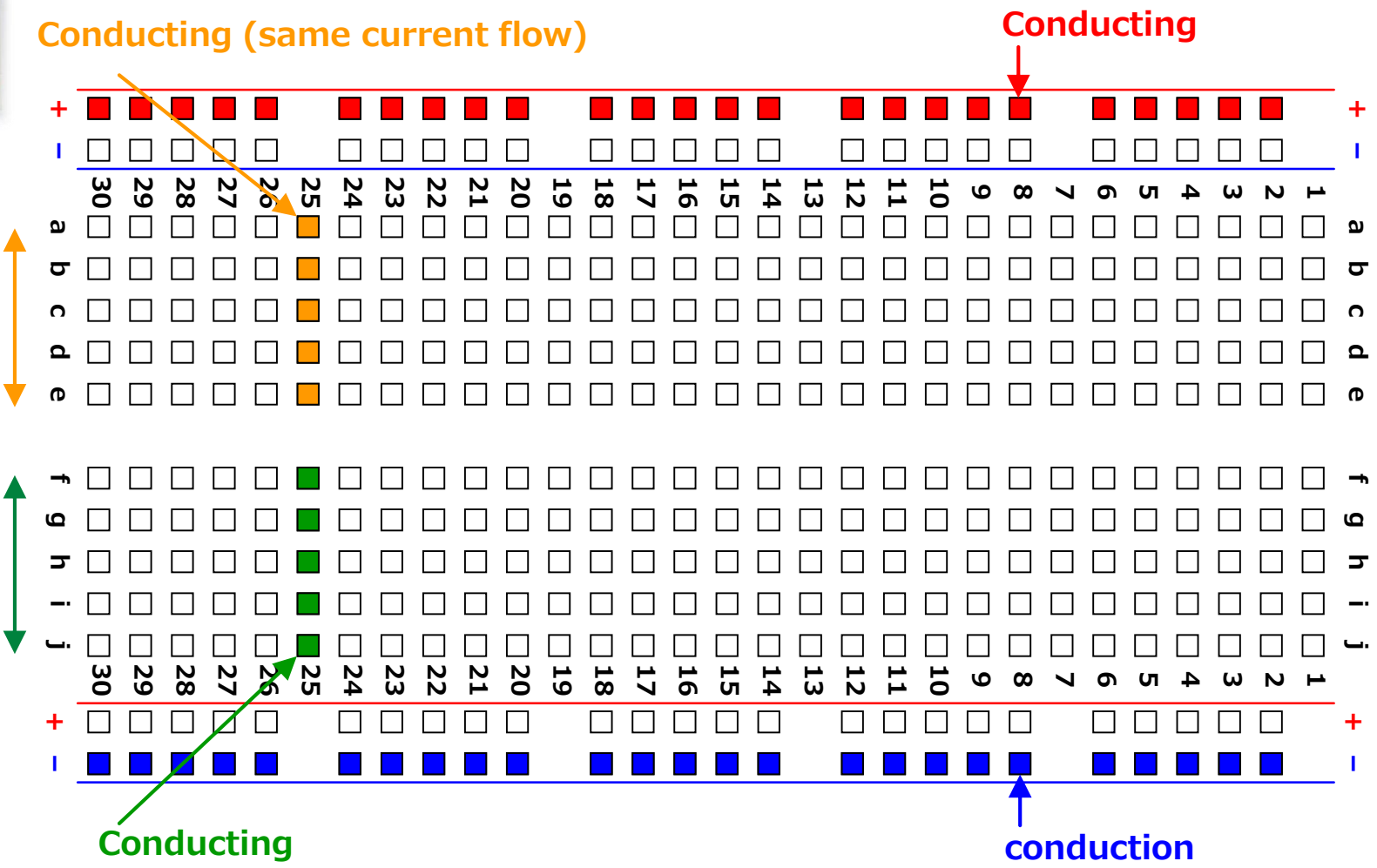


Measureable range:



Breadboard

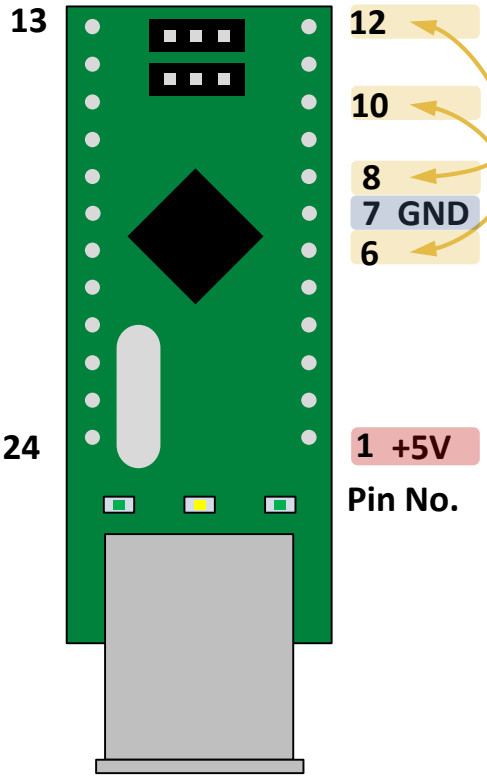



Conducting (same current flow)
Conducting
Not conducting between lines of (a)-(e) and (f)-(j).
Conducting
conduction

Connect LFR to v-duino (1)　1/3

Convert USB to serial comm interface（UART）：

USB host driver (VDIP1)

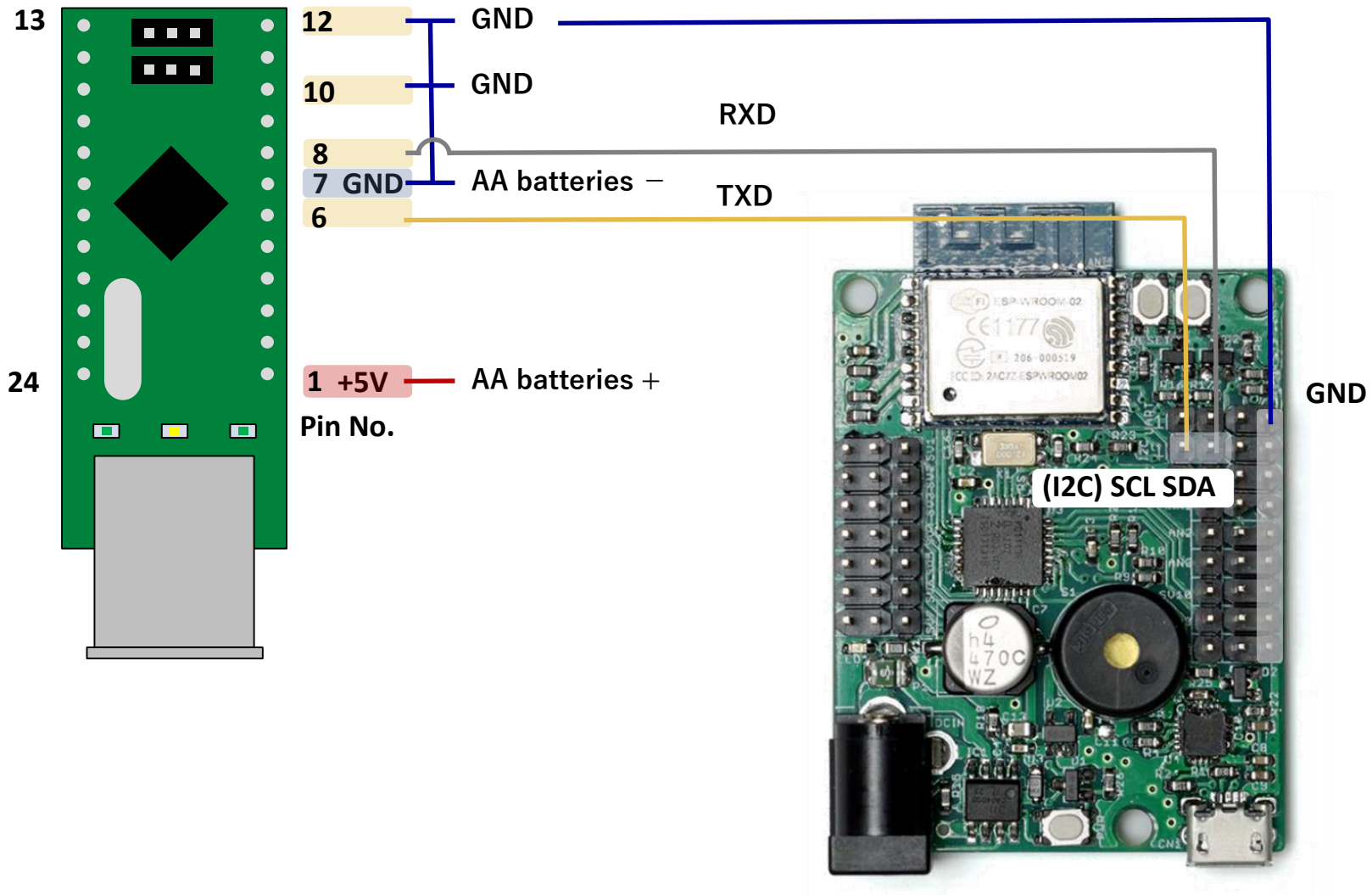


I/O pin configuration for UART interface

No.	Name	Type	Description	
6	TXD	Output	Transmit asynchronous data output	
8	RXD	Input	Receive asynchronous data output	
9	RTS#	Output	Request to send control signal	**Not in use**
10	CTS#	Input	Clear to send control signal	
11	DTR#	Output	Data terminal ready control signal	**Not in use**
12	DSR#	Input	Data set ready control signal	
13	DCD#	Input	Data carrier detect control input	**Not in use**
14	RI#	Input	Ring indicator control input	
15	TXDEN#	Input	Enable transmit data for RS485 designs	

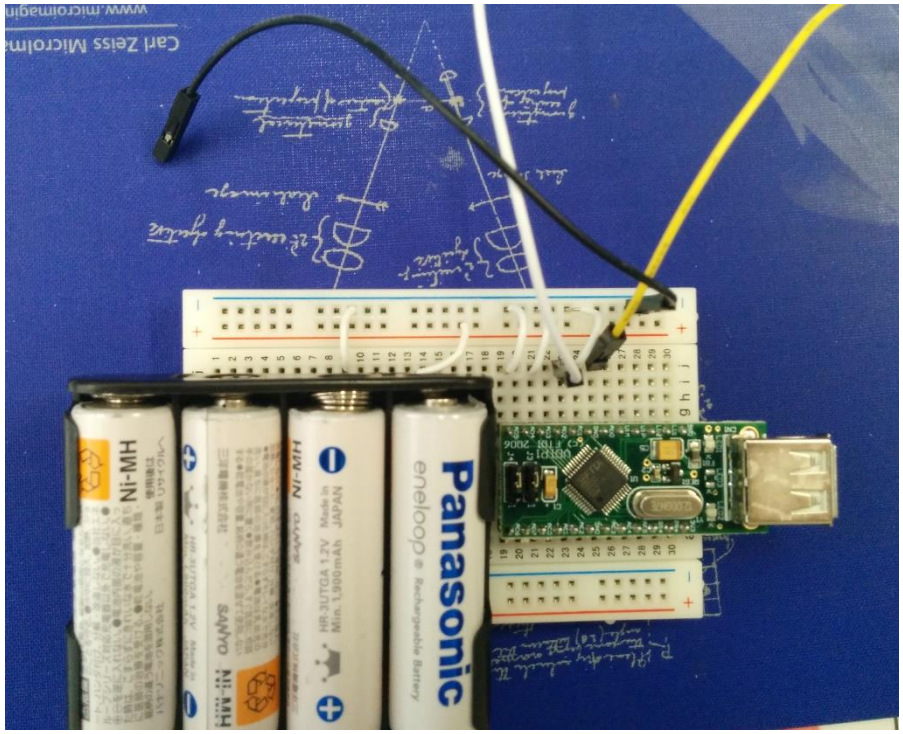
Connect LFR to v-duino (1)　2/3

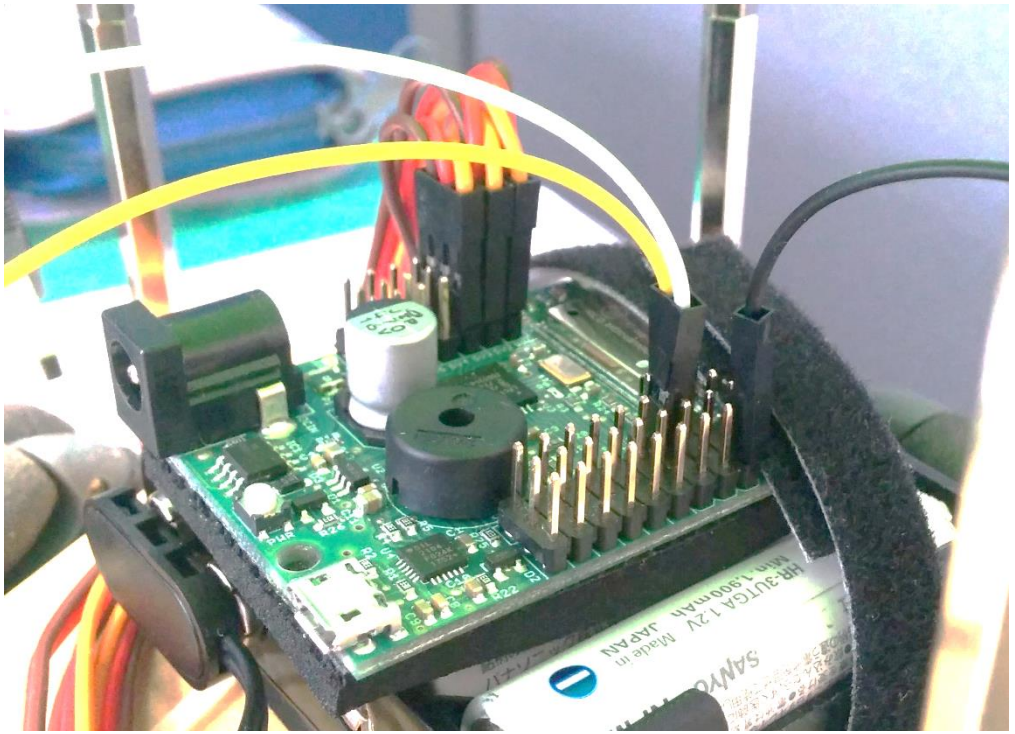
Software serial comm :



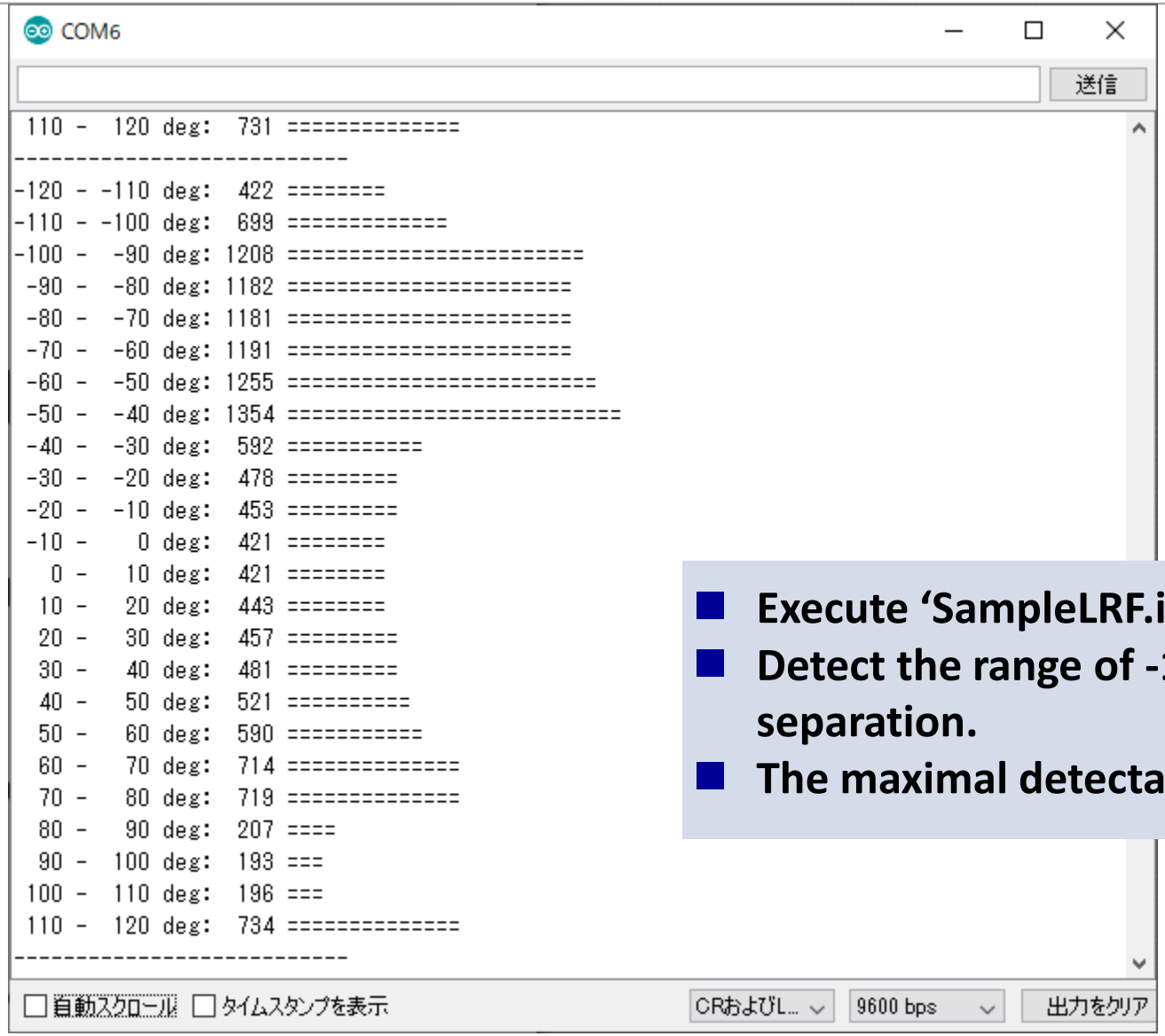
Connect LFR to v-duino (1) 3/3

Software serial comm :





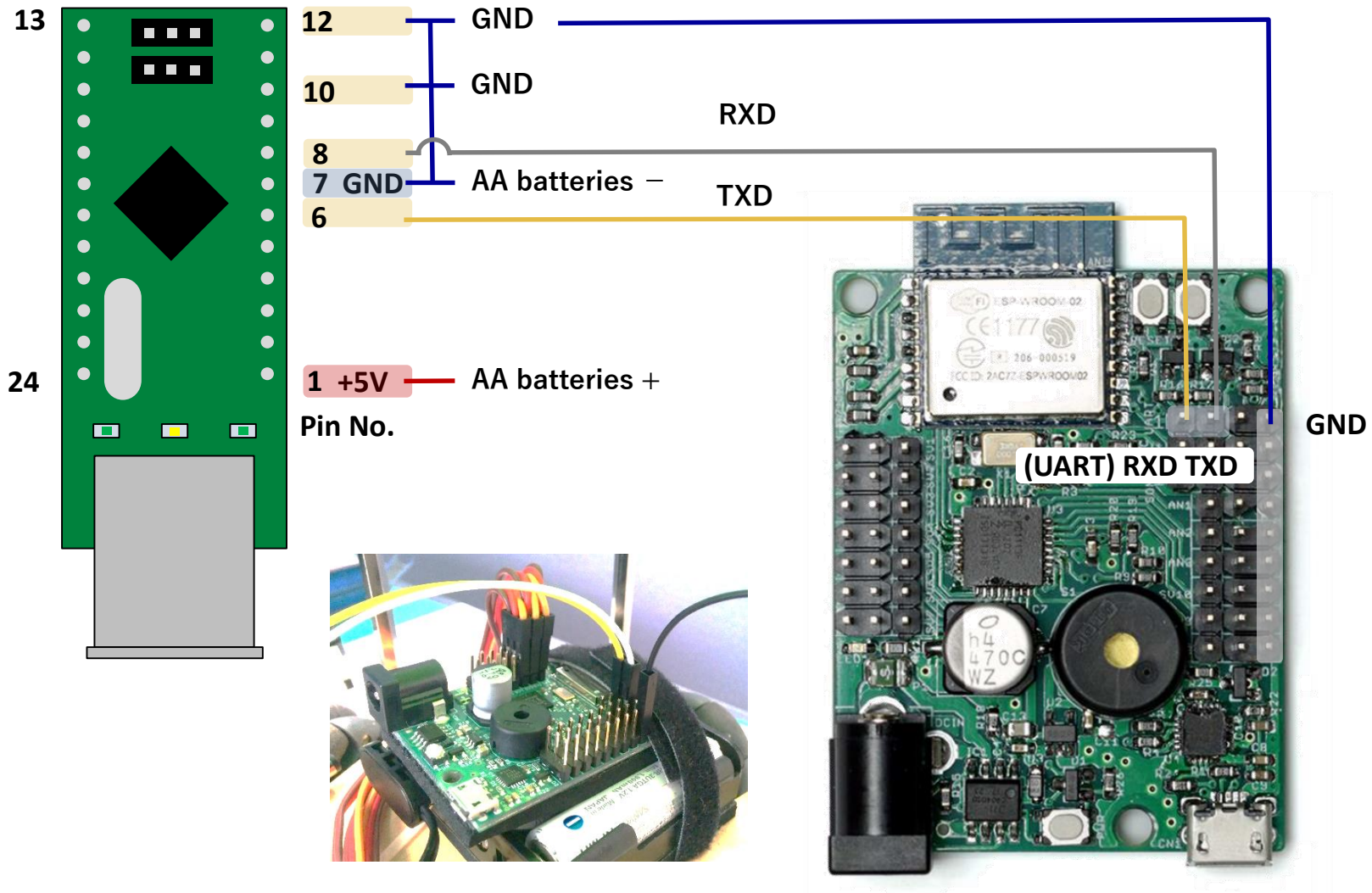
Receive data from the LRF



- Execute ‘SampleLRF.ino’.
- Detect the range of -120°~120° with 10° separation.
- The maximal detectable length is about 4 m.

Connect LFR to v-duino (2)

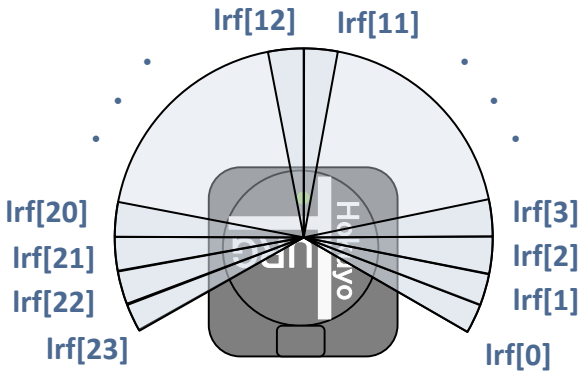
Hardware serial comm :



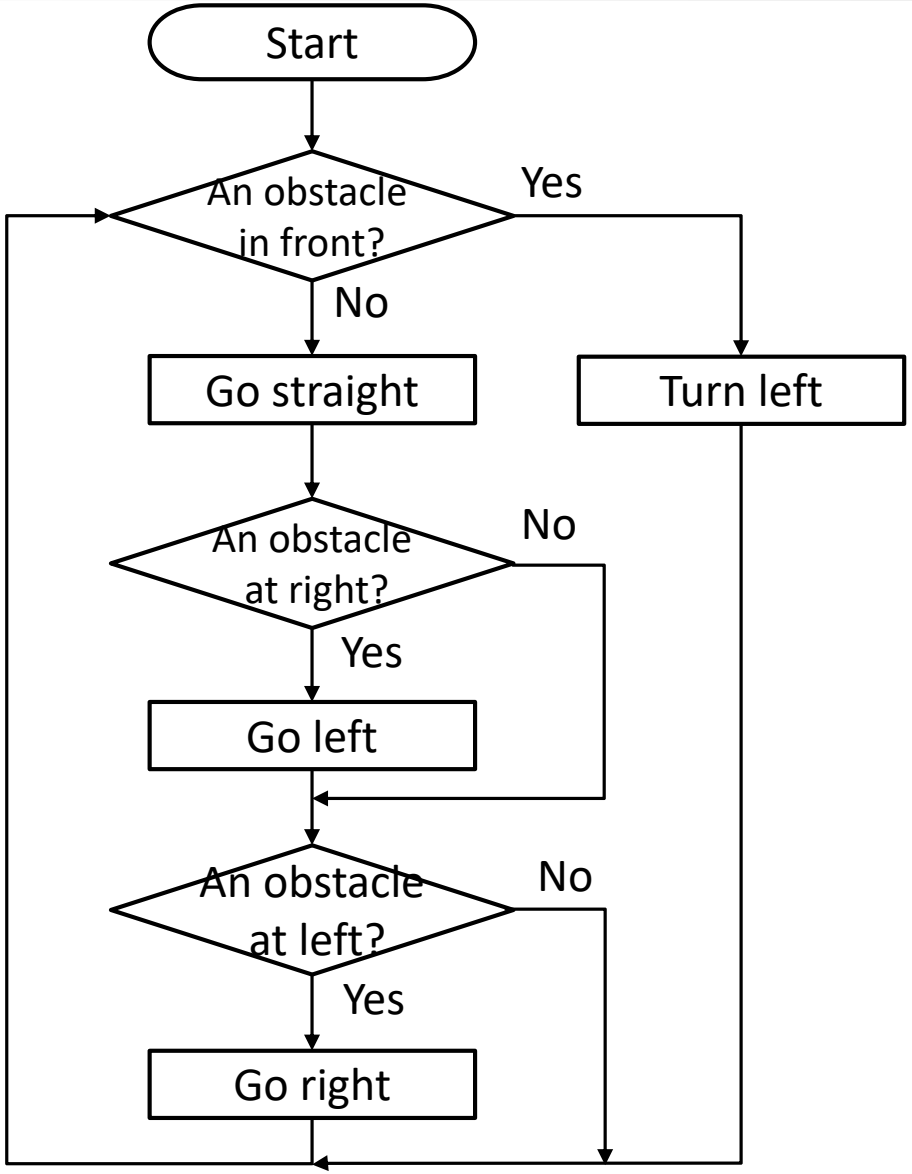
Feedback control using LRF

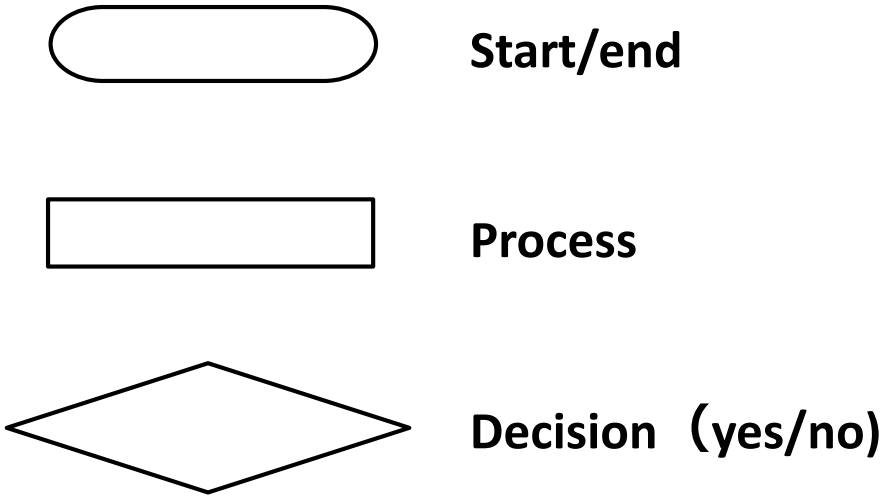
- **Make a sketch referring to “SampleObstcleAvoidance.ino” to circle around an obstacle using the LRF.**

Data assignment of the LRF :



Flowchart





- **Make a flowchart of your sketch circling an obstacle.**

Final Project

- TBA