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A Cost-Effective Multisensor Based Framework to Assist Visually Disable Person

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***Abstract*—Many of the people around us are visually impaired by born or by accident. Life-leading like normal people is the daydream to these unlucky people. This paper proposes a system, which can be a helping hand to these visually disable persons. The experiment is done with a cane decorated with our self-made Arduino UNO, Ultrasonic Sonar sensor, Passive Infrared sensor (PIR sensor), Infrared sensor (IR sensor), SD card, vibrator, buzzer etc. This system can measure the distance of any movable or static object and velocity of any movable object, identify pothole in front of the user and notify them. The total process is done in 3 different environments and for each of the environment 2 visually impaired people are used. The average accuracy for distance and velocity measurement by ultrasonic sonar sensors is 94.45% and 89.097% respectively. The average pothole detection accuracy is 90.28%. The framework is very affordable to make as the cost is $11 and easy to use in real life.**

***Index Terms*—Arduino UNO, Ultrasonic Sonar sensor, Passive Infrared sensor (PIR sensor), Infrared sensor (IR sensor), Visually impaired persons.**

I. Introduction

According to the report of the World Health Organization (WHO), at least 2.2 billion people have a vision impairment or blindness all over the world. The leading causes of vision impairment are diabetic retinopathy, glaucoma, trachoma, corneal opacity, age-related macular degeneration etc. There is some variation in the causes of vision impairment across countries. The majority of people with vision impairment are over the age of 50 years [1], [2]. We are motivated to do the work after feeling and analyzing the problems of these unlucky people.

Normally these visually impaired persons use a cane to move from here to there. If we can add some instruments like sensors, vibrators etc controlled by cost-effective self-made Arduino UNO, then it will become a great thing to them. Here, we can say that the user is using a simple cane as previous but this cane can be a blessing to them and make them independent even in the busy place or road. Some technologies like Electronic Travel Assistance (ETA) [3] are also suggested previously but these tools are not easily usable for visually disable people.

In our work as previously said, an Arduino UNO was used to control the whole system and this product was fully made by ourselves. Ultrasonic sonar sensor detected the distance of all the objects like people, static obstacles, vehicles like bicycle, car and rickshaw etc in front of the user. PIR sensor was used to detect if there is any movaable object in front of the user or not. If it is movable only then the Ultrasonic sonar sensor measured the velocity of the coming objects. Using the distance of the movable object, we've calculated the velocity of the coming object. There was a vibrator that gave the signal to the user according to the distance and velocity. There was one IR sensor in the footer of the cane which was used to identify the pothole by measuring the depth of the hole from the normal surface. When there is a hole in front of the user, the buzzer will notify the user. The whole process was experimented in 3 different environments like Busy road with low speedy vehicles, people, and static obstacles, surface with holes etc, a quiet environment like a park with people, static obstacles, rough surface etc. In every environment, there were 2 persons in every experiment. Finally, the performances were found of these 3 environments and compared with real time value and found that our proposed system works very nicely with our self-made Arduino UNO.

So, the contribution of this work to this domain includes:

1) Making Arduino UNO by ourselves which is low cost compared to the real Arduino UNO.

2) Making the device with combinations of three types of sensors like ultrasonic sonar sensor, PIR sensor and IR sensor.

3) New features like velocity measurement, distance measurement and pothole detection are added.

4) Experimenting in different environments and finding out the accuracy compared with real data and notifying the user.

Following sections provide more details about the whole system. Section II explains some of the previous works in this domain. section III explains the flowchart of the total system, instrument making process, working procedure, section IV speculates and compares the results obtained from different environments. Finally, section V concludes the overall processes and future plan for this work.

II. Literature Review

Several systems are developed to aid visually impaired persons. Most of them are designed with microcontrollers that are available in the market.

Ulrich et al. [4] designed a tool named Guide-Cane which can detect deficient barriers accurately in front of the user but can't detect obstacles on the floor. D. Yuan et al. [5] developed a virtual white cane to enhance the movement of blind, but large in-size, detect limited obstacles, and difficult to operate in public places.

Some recent sensor-based technology has been developed [6]–[8] called electronic travel aid devices to assist the visually impaired persons by providing scope of barriers information but unable to give details such as motion state, velocity, and pothole.

In paper [9], the distance of objects is measured by ultrasonic sonar sensor except for velocity. Al-Fahoum et al. [10] proposed a smart blind guidance system based on the IR sensor which works in the predetermined environment to detect types of material, shape and for measuring distance. Here, the environment needed to be predetermined. Olanrewaju et al. [11] developed the device iWalk which detects obstacles using an ultrasonic sonar sensor but they only consider distance with ultrasonic sonar sensor and presence of water. In this paper, distance of coming objects, velocity of coming objects, pothole, static objects etc are considered to be measured. Our proposed device is easy to use, low cost by using self-made Arduino UNO, performs well in unknown environment and calculation of every portion of the work is simple.

III. Methodology

The overall system is divided into some parts like the velocity of the movable object detection, distance of any detected object, pothole detection and send notifications to the blind people. Fig. 1 represents the overall processes.

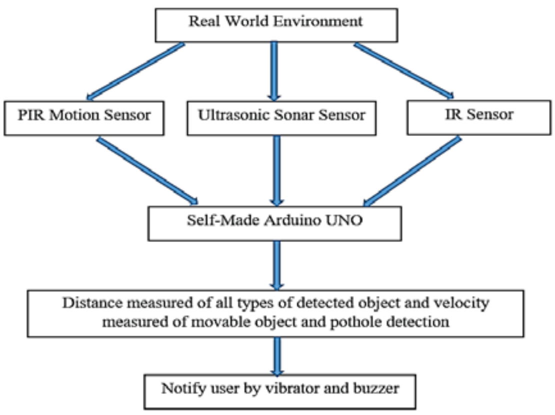

Fig. 1. Overview of the proposed system.

A. Basic Principles

Short and high-frequency sound pulses are used to detect objects by ultrasonic sonar sensor. The range of this sensor is 2cm to 400cm normally. The distance is calculated based on the time-span between the emittedsignal and receivedecho. If S is the measured distance, V is the velocity of sound in air and T is the time-span. The distance can be measured by Eq (1)

$$S = V \times T \tag{1}$$

Using infrared radiation by a pyroelectric sensor, movable objects can be detected which is in the range of 10m approximately. Every object produces heat and this sensor detects that heat to find out if it is moving or not [12]. If q represents heat transfer from the emitter, C defines the multiplication of area and emissivity of the emitting surface, the absolute temperature of the emitting and cooler surface is reflected by T, then according to Stefan-Boltzmann law, the density of heat flow between the source and the heated surface expressed as Eq (2) [13]-

$$q(\tau) = \sigma.C(T_2^4 - T_1^4) \tag{2}$$

If the object is found movable by PIR sensor then the velocity can be measured by the measured distance using ultrasonic sensor. Here, the distance is always changing as the object is moving and time span is also changing according to the movement of the object.

An IR sensor consists of IR LED named Photo–Coupler and IR Photodiode named Opto–Coupler. When there is any hole with some depth, the IR transmitter emits radiation and some of the radiation reflects to the IR receiver [14]. Based on the intensity of the reception by the IR receiver, the output of the sensor is defined.

B. Experimental Setup

In this work, the overall system is controlled by our self-made Arduino UNO, which made our experiment less costly. We have used atmega328p here, which is a single-chip microcontroller. PL2303 USB Board (mini), 16MHz Crystal Oscillator, LM7805 Voltage Regulator etc. are also used here. Our self-made Arduino UNO is shown in Fig. 2. After that, distance, velocity and pothole measurement are done sequentially. The structure of the system is described in Fig. 3.

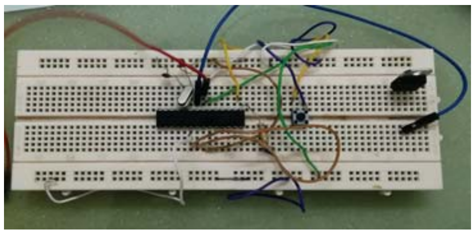

Fig. 2. Experimental Setup of our self-made Arduino UNO.

C. Working Procedure

There are two different parts in the whole system. First one is to measure distance and velocity of the coming or static object in front of the user. Second one is the detection of the pothole in the rough surface. In Fig. 4, the overall working procedure is explained. There were 6 visually impaired persons in our experiment. We have experimented in 3 environments like-

1) Busy road with low speedy vehicles, people, static obstacles and surface with potholes.

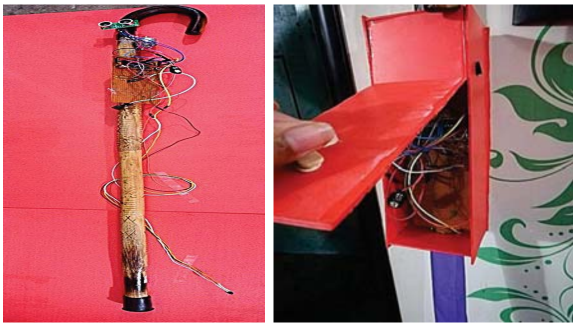

Fig. 3. Structure of the proposed system.

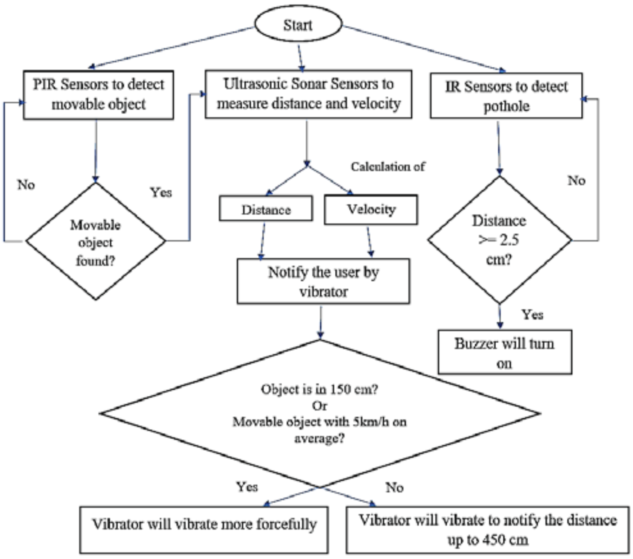

Fig. 4. Working procedure of the system.

2) Quiet environment like a park with people, static obstacles and surface with potholes.

3) Only static obstacles with potholes.

For each of the environments, 2 blind persons were used. So, there are 6 experiments overall.

The threshold value for ultrasonic sonar sensor and PIR sensor is 150cm, for IR sensor it is 2.5cm as it is measuring pothole. As we can see in Fig. 4, ultrasonic sonar sensor will detect distance of every object in front of the user. PIR sensor will detect if there is any movable object or not in front of the user. If the object is not moving then the ultrasonic sonar sensor will detect the distance only. But if the object is moving then the ultrasonic sensor will detect both distance and velocity of the moving object. When an object is moving in front of the user, the distance will be changing continuously. Using the changing rate and time span between this changing, the average velocity of 5 seconds was measured. Here, the notification will be generated by a vibrator. If the object is not moving within 150cm to 450cm then the vibrator will vibrate slowly. If the object is in motion with 5km/h velocity or within 150cm, it will vibrate more forcefully to notify the user.

IR sensor will detect if there is any pothole on the surface. Here, a notification will be generated using a buzzer. If the depth of the hole is greater than 2.5cm from the surface then the buzzer will make a sound to notify the user.

IV. Experimental Results

As mentioned previously, there are used 3 environment and 2 blind people per environment to complete the experiment. There are 3 different types of results for 3 different sensors for each of the environments. The necessary results are stored in the SD card for further use. The accuracy that means the correct detection of movable objects and hole detection are measured by Recall, Precision, and Accuracy where-

$$Recall = \frac{TP}{TP + FN} \tag{3}$$

$$Precision = \frac{TP}{TP + FP} \tag{4}$$

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \tag{5}$$

Here,
TP = True Positive, TN = True Negative, FP = False Positive, FN = False Negative .

The result of the ultrasonic sonar sensor for distance and velocity was compared with the real distance and velocity. Again the depth of the pothole is also checked whether the IR sensor is giving the accurate result or not and compared with the real depth of the pothole.

A. Result of First Environment

In this environment, we kept 2 low speedy vehicles, 3 people, 2 static objects and there were 3 potholes on the surface. Among them, 5 objects were moving. The results of our system for environment 1 are shown using Table I, Table II, Table III, Table IV, Table V, Table VI and Table VII. Again, the graphical scenario of the measured distance and velocity and actual distance and velocity using ultrasonic sonar sensor and measured depth and actual depth of potholes using IR sensor are shown using Fig. 5.

TABLE I
Detection of Moving Objects by PIR Sensor for Environment 1

No. of Experiment	No. of Moving Object	TP	TN	FP	FN
1	5	4	1	0	0
2	5	3	1	0	1

B. Result of Second Environment

In this environment, we kept 4 people, 3 static objects and there were 3 potholes on the surface. Among them, 4 people were moving. The results of our system for environment 2 are shown using Table VIII, Table IX, Table X, Table XI, Table XII, Table XIII and Table XIV. Again, the graphical scenario

TABLE II
AVERAGE VALUE OF RECALL,PRECISION AND ACCURACY WITH PIR SENSOR FOR ENVIRONMENT 1

	Experiment no. 1	Experiment no. 2	Average Value
Recall %	100	100	100
Precision %	80	75	77.5
Accuracy %	80	80	80

TABLE III
DISTANCE MEASUREMENT WITH ULTRASONIC SONAR SENSOR FOR ENVIRONMENT 1

Objects	Actual Distance (cm)	Measured Distance for 1 (cm)	Measured Distance for 2 (cm)	Error for 1 %	Error for 2 %
People 1	6	7.2	6.1	20	1.67
People 2	10	11.76	9.73	17.6	2.7
People 3	16	15.23	16.5	4.81	3.13
Static Object 1	25	23.8	26.04	4.8	4.16
Static Object 2	40	43.7	41.1	9.25	2.75
Car 1	100	98.3	101.78	1.7	1.78
Car 2	150	151.5	147.8	1	1.47

TABLE IV
VELOCITY MEASUREMENT FOR ENVIRONMENT 1

Objects	Actual Velocity (km/h)	Measured Velocity for 1 (km/h)	Measured Velocity for 2 (km/h)	Error for 1 %	Error for 2 %
People 1	5	5.85	5.7	17	14
People 2	5.8	6.20	6	6.89	3.45
People 3	6	6.52	7.24	8.67	20.67
Car 1	15	13.83	14	7.8	6.67
Car 2	22	23.56	24	7.1	9.01

TABLE V
DETECTION OF POTHOLE WITH IR SENSOR FOR ENVIRONMENT 1

No. of Experiment	No. of Pothole	TP	TN	FP	FN
1	3	3	0	0	0
2	3	2	0	1	0

TABLE VI
AVERAGE VALUE OF RECALL,PRECISION AND ACCURACY WITH IR SENSOR FOR ENVIRONMENT 1

	Experiment no. 1	Experiment no. 2	Average Value
Recall %	100	100	100
Precision %	100	66.67	83.34
Accuracy %	100	66.67	83.34

TABLE VII
DEPTH MEASUREMENT WITH IR SENSOR FOR ENVIRONMENT 1

Objects	Actual Distance (cm)	Measured Distance for 1 (cm)	Measured Distance for 2 (cm)	Error for 1 %	Error for 2 %
Pothole 1	3.5	4	4.8	14.28	37.14
Pothole 2	5	6	5.5	20	10
Pothole 3	7	8.35	8.49	19.29	21.29

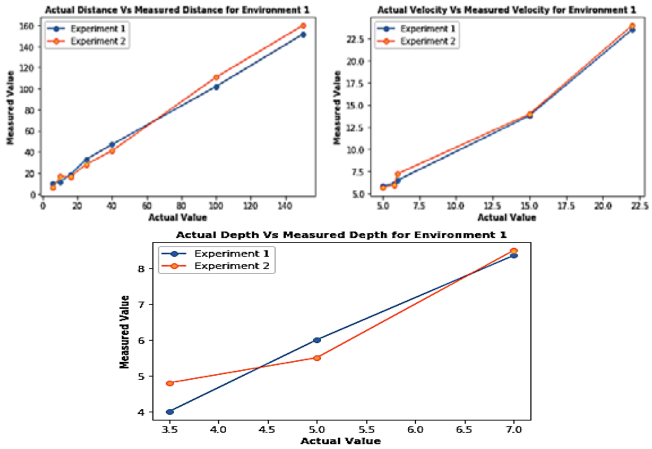

Fig. 5. Graphical Representation of Actual Vs Measured Distance, Velocity and Depth of Pothole for Environment 1.

of the measured distance and velocity and actual distance and velocity using ultrasonic sonar sensor and measured depth and actual depth of potholes are shown using Fig. 6.

TABLE VIII
DETECTION OF MOVING OBJECTS BY PIR SENSOR FOR ENVIRONMENT 2

No. of Experiment	No. of Moving Object	TP	TN	FP	FN
1	4	3	0	0	1
2	4	4	0	0	0

TABLE IX
AVERAGE VALUE OF RECALL,PRECISION AND ACCURACY WITH PIR SENSOR FOR ENVIRONMENT 2

	Experiment no. 1	Experiment no. 2	Average Value
Recall %	75	100	87.5
Precision %	100	100	100
Accuracy %	75	100	87.5

C. Result of Third Environment

In this environment, we kept 5 static objects and 4 potholes on the surface. The results of our system for environment 3

TABLE X
DISTANCE MEASUREMENT WITH ULTRASONIC SONAR SENSOR FOR ENVIRONMENT 2

Objects	Actual Distance (cm)	Measured Distance for 1 (cm)	Measured Distance for 2 (cm)	Error for 1 %	Error for 2 %
People 1	5	5.12	6.2	2.4	24
People 2	12	14.25	12.3	18.75	2.5
People 3	16	16.18	16.2	1.13	1.25
People 4	23	24.11	24.32	4.82	5.73
Static Object 1	45	46.44	47.6	3.2	5.78
Static Object 2	58	59	59.64	1.72	2.82
Static Object 3	75	73.9	76.18	1.46	1.57

TABLE XI
VELOCITY MEASUREMENT FOR ENVIRONMENT 2

Objects	Actual Velocity (km/h)	Measured Velocity for 1 (km/h)	Measured Velocity for 2 (km/h)	Error for 1 %	Error for 2 %
People 1	5.3	5.8	6	9.43	13.20
People 2	6.5	7.2	7.4	10.76	13.84
People 3	10	11	11.3	10	13
People 4	14	15.5	15.75	10.71	12.5

TABLE XII
DETECTION OF POTHOLE WITH IR SENSOR FOR ENVIRONMENT 2

No. of Experiment	No. of Pothole	TP	TN	FP	FN
1	3	2	0	0	1
2	3	3	0	0	0

TABLE XIII
AVERAGE VALUE OF RECALL,PRECISION AND ACCURACY WITH IR SENSOR FOR ENVIRONMENT 2

	Experiment no. 1	Experiment no. 2	Average Value
Recall %	100	100	100
Precision %	100	100	100
Accuracy %	100	100	100

TABLE XIV
DEPTH MEASUREMENT WITH IR SENSOR FOR ENVIRONMENT 2

Objects	Actual Distance (cm)	Measured Distance for 1 (cm)	Measured Distance for 2 (cm)	Error for 1 %	Error for 2 %
Pothole 1	2.9	3.5	3.65	20.69	25.86
Pothole 1	4	4.78	5	19.5	25
Pothole 3	5.6	6.34	6.8	13.21	21.42

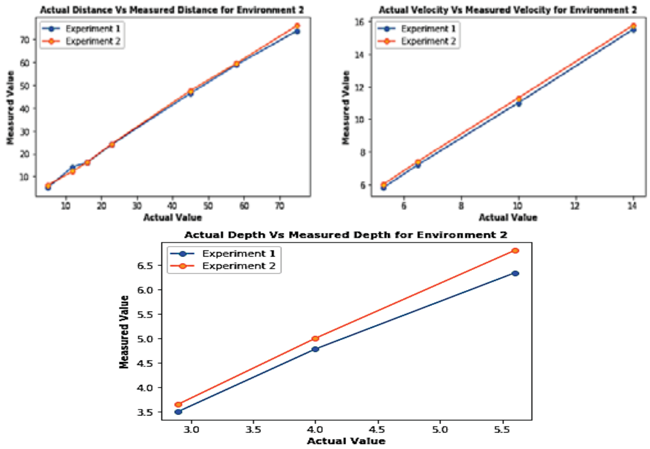

Fig. 6. Graphical Representation of Actual Vs Measured Distance, Velocity and Depth of Pothole for Environment 2.

are shown using Table XV, Table XVI, Table XVII and Table XVIII.

TABLE XV
DISTANCE MEASUREMENT WITH ULTRASONIC SONAR SENSOR FOR ENVIRONMENT 3

Objects	Actual Distance (cm)	Measured Distance for 1 (cm)	Measured Distance for 2 (cm)	Error for 1 %	Error for 2 %
Static Object 1	7	5.8	8.04	17.14	14.86
Static Object 2	14	12.2	15.4	12.86	10
Static Object 3	22	24	21.1	9.09	4.09
Static Object 4	34	34.4	36.1	1.18	6.18
Static Object 5	40	41.6	38.1	4	4.75

Again, the graphical scenario of the measured distance and actual distance using ultrasonic sonar sensor and measured depth and actual depth of potholes are shown using Fig. 7.

If we consider the cost of making the system, we can see that our system is less costly. If we compare our distance measurement with ultrasonic sonar sensor controlled by our self-made Arduino UNO and real Arduino UNO [11], the result is shown in Table XIX. Same as the distance, the average accuracy for velocity measurement using ultrasonic sonar sensor is 89.097% and the average accuracy of pothole detection is 90.28%.

TABLE XVI
DETECTION OF POTHOLE WITH IR SENSOR FOR ENVIRONMENT 3

No. of Experiment	No. of Pothole	TP	TN	FP	FN
1	4	3	0	1	0
2	4	4	0	0	0

TABLE XVII
AVERAGE VALUE OF RECALL,PRECISION AND ACCURACY WITH IR SENSOR FOR ENVIRONMENT 3

	Experiment no. 1	Experiment no. 2	Average Value
Recall %	100	100	100
Precision %	75	100	87.5
Accuracy %	75	100	87.5

TABLE XVIII
DEPTH MEASUREMENT WITH IR SENSOR FOR ENVIRONMENT 3

Objects	Actual Distance (cm)	Measured Distance for 1 (cm)	Measured Distance for 2 (cm)	Error for 1 %	Error for 2 %
Pothole 1	4.75	4	5.8	15.79	22.15
Pothole 2	5	5.89	3.5	17.8	30
Pothole 3	8.9	7.87	10.04	11.57	12.81
Pothole 4	10.2	12.9	9.76	26.47	4.31

D. Discussion

In this paper, with our self-made Arduino UNO, 3 types of sensors measured some values in 3 different environments. The result shows that our proposed system provides better accuracy and the cost is very low with comparison to real Arduino UNO.

V. CONCLUSIONS

Many of us think that visually impaired or blind people are the curse of our society. This thinking is not true rather these people can be an asset of our society if we make the movement easy to them as normal people. This paper tried to make a helping hand for these people. This work completed with lower cost and comparatively higher accuracy so that poor people can also afford this system in their daily life. The accuracy of this system is almost close to the real value and the self-made Arduino UNO gave promising support like real Arduino UNO.

In this paper, we only think about the environment in front of the user. In the future, we want to add the all-around environment of a user. We also want to add a water level detection system and image processing to this system to make it more helpful to the visually impaired persons.

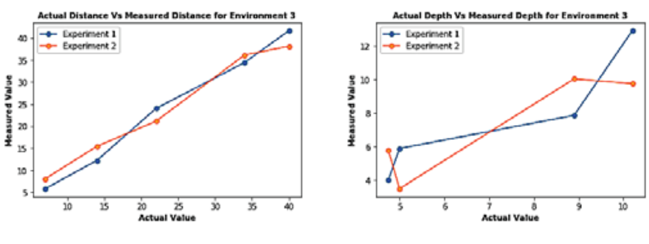

Fig. 7. Graphical Representation of Actual Vs Measured Distance and Depth of Pothole for Environment 3.

TABLE XIX
COMPARISON OF COST OF FULL SYSTEM AND ACCURACY FOR DISTANCE MEASUREMENT USING ULTRASONIC SONAR SENSOR

	System with our self made Arduino UNO	System with real Arduino UNO
Cost	\$ 11	\$ 15
Accuracy (%)	94.45	90

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