

Theoretical Concepts of Dimension Measurement through Devices Wearable on Human Fingers

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Abstract—Calculating distances and measuring dimensions are a common job in labs, technical concerns and industries, amongst other places. We have a large number of measuring devices at our disposal. Some devices for everyday use are fairly accurate and provide us the required data, while others are extremely accurate and sensitive and require a bit more knowledge and expertise. These devices can be hand-held like Micrometers, kept on a surface like Height Gauges or require a lot of space like the CMM. Whereas others might be usable under specific conditions and some might include transmitters and sensors. Whatever be the case, man has always found that accurate measurement requires time. It gets further complicated and time consuming if the part or object we are measuring, is irregular. Majority of such cases deals with the use of more than one measuring instrument. The future of measuring instruments and equipments require them to be fast, accurate and easy to use but also compact. Theoretical concepts for this kind of a futuristic but feasible instrument have been taken under study. In this paper, we have focused on the theoretical concepts and conception of a measuring instrument which can be worn on human fingers. Various possibilities of creating such a device are explored and the underlying principles have been discussed. It can be thought of as a pre-designing stage where all the ideas and its advantages and shortcomings are discussed. The main theme of the paper is to make the idea of having a measuring device that we can wear on our fingers, possible. Possible future uses of such devices have also been included.

1. INTRODUCTION

We use a large number of dimension measuring instruments in our daily work. These are the measuring instruments that are used to estimate physical dimensions such as height, width, thickness, angle, amongst other variables. There are also a large number of metalworking tools (instruments and gauges) and machines in use. Some instruments are hand-held and are thus portable while others are bulky and require the job to be taken to it, for dimensional measurement. Each instrument has its unique feature that makes it invaluable, in its own way for measuring the physical geometrical characteristics of an object. Though these instruments have critical uses on a daily basis, there are some disadvantages that each instrument has.

Disadvantages of some measuring instruments include: -

1. Instruments like Vernier Calipers and Micrometers provide fairly accurate reading but are prone to error. This error occurs due to its gradual wear out.
2. The above mentioned instruments also provide erroneous result while measuring irregular objects.
3. Vertical measuring instruments like the Height Gauge have a heavy base and require an accurately flat, smooth underside. The surface table on which it is kept must also be extremely smooth and flat.
4. Coordinate measuring machines provide very accurate dimensions but require skilled operators and are not portable. They also consume time.
5. Sensitive instruments like dial gauges are also prone to damage. The readings vary over prolonged use and any impact might permanently damage it.
6. There is no universal dimensional instrument which is portable, measures irregular objects with ease and provides accurate results without error, over time.

These shortcomings still make these dimension measuring devices a must have for various jobs. However, the future of these can be expanded and multiple features can be incorporated into one measuring device.



Fig. 1: Some dimensional measuring instruments commonly required in various work

2. THEORY

The theoretical dimension measuring device has to be worn on our fingers to be used. It consists of four thimble-like gadgets, two for each hand, worn on the thumb and index fingers. One pair of these devices will be connected to a digital display, which can be worn as a wrist watch on the arm. Measurements are taken through directly touching the thimble-like devices to the job and the resulting measurement will be displayed on the digital screen. These finger-attached devices contain transmitters and sensors which will be used to measure the dimension of objects. Coordination of the four transreceivers is important in establishing a correct and accurate result. Since the device is attached to the human fingers and hand, the limitation to how far we can measure, for a single user, is typically the length of the outstretched hand. This varies with each user wearing the device and depends on the height of the individual (total arm span is usually related to an individual's height [1]). The device can be worn by two users also to measure large dimensions.

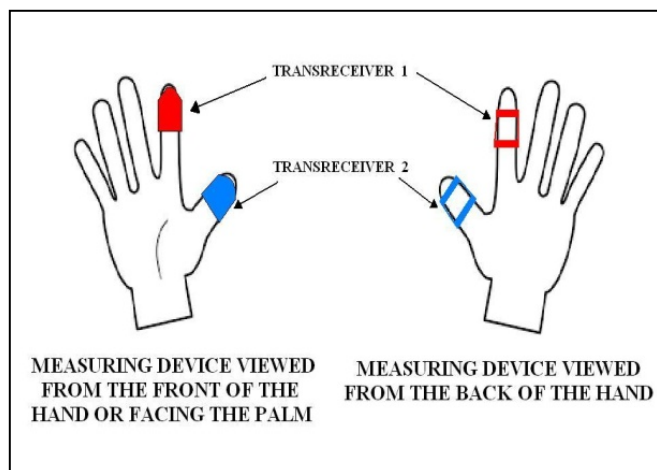


Fig. 2: One pair of transreceivers shown for the right hand. A single transreceiver consists of a transmitter to send a form of signal and a sensor to receive it. The pair is in red and blue.

The transreceivers contain a transmitter to send a waveform of energy out and a sensor to receive that energy. Together with the time taken between such an interaction and the speed of the wave will be used to measure the distance between the object. This is because the object whose dimension needs to be measured will be sandwiched between the two transreceivers. These two transreceiver can be on one hand or one from each hand. This is one scenario. In other scenarios, three transreceivers will be required to measure the distance and hence the dimension (like length, breadth, outer diameter etc.). In this case, any one transreceiver acts as a transmitter or energy source and the other two transreceivers act as a sensor to receive the waveform or signal. In the first case, the signal transmitted must penetrate the object measured and in the latter case, the signal transmitted may or may not penetrate the object measured.

Two types of transmitters and receivers are used in this theoretical study. Ultrasonic signals are primarily discussed waveform. The possibility of radio waves is also not ruled out. The only disadvantage radio waves have is that they interact with metals and cannot be used to measure them. Low power ultrasounds (like those used in Non-destructive testing) do not suffer from such hindrances. The working principles behind the theoretical device, as stated earlier, have been briefly discussed.

The device under consideration uses the principle of Ultrasonic Thickness Measurement (UTM) [2] and concepts of ultrasonic thickness gauges and applies it to a device wearable on our fingers. UTM is a method of performing non-destructive measurement (gauging) of the local thickness of a solid element, typically made of metal, basing on the time taken by the ultrasound wave to return to the surface. This type of measurement is typically performed with an ultrasonic thickness gauge. Ultrasonic waves have been known to travel through metals at a constant speed characteristic to a given alloy. The wave is usually emitted by a piezoelectric cell (or an EMAT Sensor [3]) that is built into the measurement sensor head and the sensor is used to record the reflected wave. The sound wave has a spherical pattern of propagation and the measurement is its first recorded return. It will normally be the head of the emitted wave traveling at the shortest distance which is equivalent to the thickness of the sample. All other returns can be discarded or might be processed using more complicated strategies.

The wearable device incorporates radio waves applying from the concepts of Radio Direction Finder (RDF) [4]. Using two or more transmissions from different locations, the location of an unknown transmitter can be determined; alternately, using two or more measurements of known transmitters, the location of a vehicle can be determined. Using similar concepts, a source transmitter of radio waves is received by two sensors on two sides of an object. The object here is the object whose dimensions are required. Through the time taken to receive the radio wave and the speed of the wave, the distance between the two sensors can be found. This is the dimension of the object. The long range of radio waves can be used as an advantage to find out long dimensions like nose-to-tip of an aircraft, faster. In this case, the device has to be worn by two separate users.

3. THEORETICAL DESIGN

The two pair of transreceivers in each hand is made up of hard plastic. It is color coded into Red, Green, Blue and Yellow, depending on the energy used for communication; the ultrasound pair being red and blue and Radio wave transreceivers being yellow and green. It can be altered depending on new additions of energy transmission and sensing. In all cases, each device will be wearable on our fingers and its size will be not more than 1"x1.5"x0.25" (width, length and height) or not larger than 25mm x 40mm x

10mm for the thumb (width, length and height), whichever is found favorable after trial testing. Each device will have two strong elastic straps on the back to hold the user's finger, when it is worn on the finger. The stretchable strap on the back of the device allows a firm fit on any finger. The profile of the device will be slightly rounded at the face touching an object, just like the design of human fingers. But, the device will be flexible to aid in measurement and not foldable.

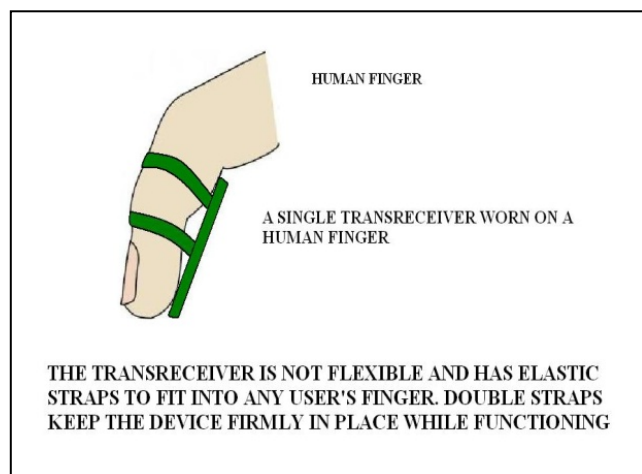


Fig. 3: A single transceiver worn on a finger

Each wearable device is as a transceiver and thus contains a transmitter and sensor embedded in it. There is a transducer here to send a signal, radio or ultrasonic sound and the receiver at the other end receives it. The receiver end will also have a transducer [5] and convert the definite signal for display and storage. The time required to receive the signal and the speed of the waveform will provide the distance. For the purpose of proper transmission of ultrasonic sound in piezoelectric transducers, a gel base (generally propylene glycol) can be used. Although, EMAT type transducers are preferred here as they do not require any liquid coupling. Both emit sound waves into the material when excited. The device will be a digital thickness measuring type and capable of saving data, with facilities of data transmission to various data logging devices. These data logging devices can be Smartphones, tablets or other handheld devices. A new form of data display device specifically used for this purpose has also been proposed. It consists of a digital data display screen, also functioning as a touch-pad, strapped on to the wrist of the user. It will also feature data editing and printing tools and have a wireless connection with modern printers. A wireless device on a printer can be used to transmit the data also. This is primarily the reason that the middle-finger of the hand is kept free, without having any wearable device. It can be used to operate the proposed new data logging device.

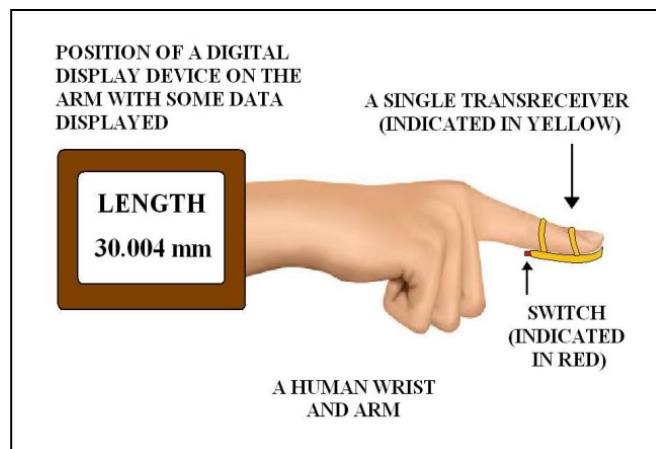


Fig. 4: The proposed data display device and its position with respect to the human arm. The complete theoretical system is shown here.

In case of radio wave transreceivers, radio waves, at a particular frequency is sent through the air from one device and received by the other device. The reason of selecting the radio waves is that large measurements can also be done by two users wearing the transreceivers. Each device must therefore be capable to both receive and send a radio wave signal. Also radio wave transmission is fast and reliable. The receiver is a digital radio receiver which functions in a similar way. The wavelength and frequency used can be within those used in various areas today.

The final piece of each transceiver is a switch. It will be used to switch on the devices for the purpose of transmission (and reception) and in turn, measurement. The proposed display device must be switched on separately and the whole system is ready to measure. The complete system is shown in Fig. 4.

4. METHOD OF WORKING

4.1 Working process using ultrasonic sound

The working of the dimension measuring device is through the transmission and reception of ultrasonic sound waves. It functions similar to Ultrasonic Thickness Gauges (UTG) [6] and uses UTM. There are two situations that can arise. First, if only one side of the job sample is available for measurement and secondly, if both sides are free to be measured. The method of measurement changes according to this.

4.1.1 The sample job is free on only one side

In case the sample job is free from one side only, the method of dimension measurement is similar to that used in UTG. Thus the device determines the sample thickness by measuring the total time sound takes to traverse from the transducer, through the sample and get reflected back. The dimension is calculated based on the speed of sound through the tested

sample. Here, only one transreceiver is placed in contact to the job and it transmits as well as receives the reflected sound wave and displays the measurement. The reading is taken at a few more places, in case of any error due to internal defects. Typically these transducers use a set frequency of 5 MHz but it can be set to any operating frequency.

4.1.2 The sample job is unobstructed on the measuring sides

When the sample job is unhindered on the measuring sides, measurements can be taken a little easier. Here, the user places two fingers on two sides of the sample to measure its dimension. The device on both the fingers acts as a relay and any one of them transmits an ultrasonic sound wave on excitation and the device on the other finger receives it. The distance is calculated on one relay journey, using the speed of ultrasonic sound in that medium. There reading no longer requires a reflected ultrasonic sound wave to find the distance as in case of UTM.

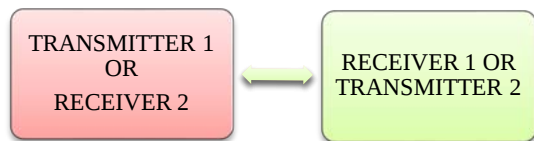


Fig. 5: Working between two transreceivers

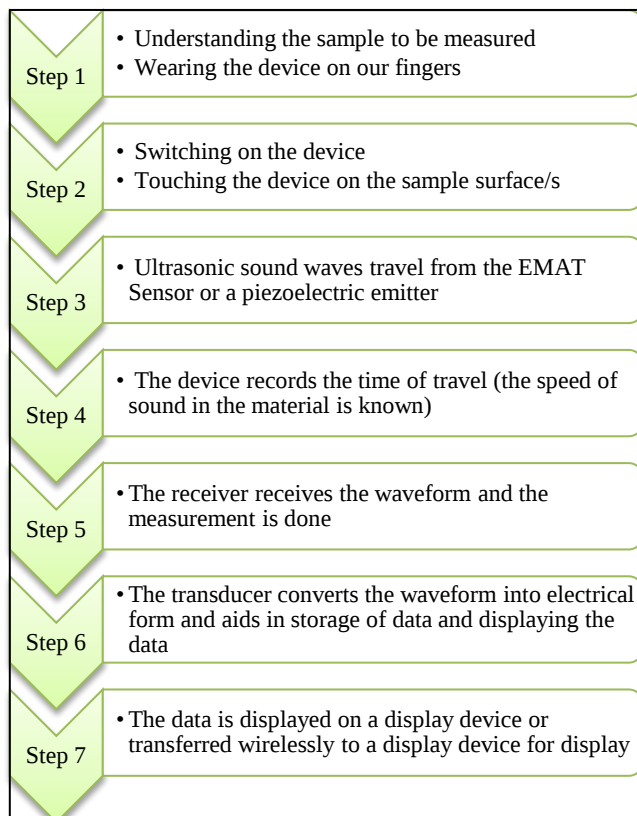


Fig. 6: Block diagram of the working of the device

The receiver is a sensor, which is basically a microphone to detect the ultrasonic noise. The transducer converts the sound to an electric signal (AC) and the further processes of data saving and display occur. A block diagram of the working of the device has been shown in Fig. 6.

4.2 Working process using radio waves

Radio waves travel fast and at a much greater range without being distorted. So, much greater distances can be easily measured. The method of working is shown in Fig. 7.

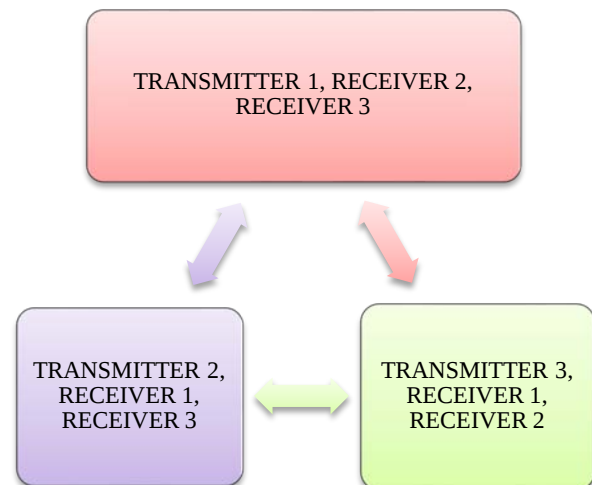


Fig. 7: Method of working of the transreceivers using radio waves

Three transreceivers are required here, which can be worn by two or three users, depending on the size and shape of the object.

Here, any of the three transreceivers can be used as the transmitter and the other two consequently becomes the receiver. The numbering is done to distinguish the fact that if any one of the boxes in the Fig. becomes the transmitter, which of the other two receives its signal wave. However, this method will not work in case of measurements on metals, as metals are known to distort radio waves and the transmission of radio waves is not proper through metals.

Upon proper interception of the radio waves transmitted by the two devices, their distance is calculated by knowing the time taken and speed of radio waves through the substance. The actual dimension to be measured is found from the knowledge of the two separate distances. For example, if we need to find the measurement of a dimension BC, we can transmit a radio signal from A and measure AB and AC. This can be used to find BC.

5. CONCLUSION

There are many advantages and disadvantages of using the discussed type of wearable dimension measuring devices. Using ultrasonic sound and radio waves as methods of

measurement has been modified to fit a device we can carry and use every day.

5.1 Advantages of using the theoretical devices worn on fingers

1. These devices can be used by anyone with little or minimal training.
2. One user or more than one user can simultaneously use this device.
3. These devices are portable and can be made extremely accurate by making better prototypes.
4. Measurement is fast and easy.
5. A display shows instant readings which can be printed out later wirelessly.
6. The devices will actually cost lesser than the present UTG methods.
7. Distance measurement using Radio waves has not been done on a small sized scale.
8. Can measure irregular objects.
9. Long distances and dimensions can be measured easily.
10. Newer concepts of sensors and transmitters can be used to modify and better these devices.
11. Can be easily deployed under any conditions.
12. Error in readings will not result from the measuring device being worn out.
13. Easily synchronized and customizable into various shapes to suit the needs of the job. The device will be flexible to suit the contours of the measuring sample.
14. Plastic can be utilized here and the prospect of 3D printing of the device parts is possible.

5.2 Disadvantages of using the theoretical devices worn on fingers

There are certain disadvantages of using these devices which can be worked upon and solved.

1. The ultrasonic testing device might require calibration before using it.
2. The accuracy of the device must be worked upon. Presently we know that measuring devices using ultrasonic sound waves and radio waves are fairly accurate.
3. The device has simple parts but assembling them might require skill. They must be made as compact as possible to fit into the measuring device.
4. May require further research and making prototypes before being ready for use.

New concepts have to be introduced for us to move ahead into the future. If we look carefully though, the pros outweigh the cons. The future holds much more and we can further our knowledge of these concepts by building newer and better devices.

6. REFERENCES

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