Range-Gating Technology for Millimeter-wave Radar Remote Gesture Control in IoT Applications

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***Abstract*— Touchless hand gesture using portable millimeter-wave radar sensors an enabling technology for Internet of Things (IoT) applications. In this paper, we investigate the feasibility of using a frequency modulated continuous wave (FMCW) radar with noise removal and range gating method to recognize human hand gesture for a user moving in the radar's field of view. These detected hand gestures will be applied to remote control of computers or smart TVs at a distance from 0.3 m to 1.2 m.**

***Keywords*— Touchless hand gesture, FMCW radar, noise removal method, range gating method, IoT applications.**

I. Introduction

Human hand gesture recognition using radar sensors has been studied extensively in the field of remote control applications. Interests in the electronics industry using smart radar for human gesture recognition has experienced significant growth in recent years. For example, Google is developing Soli radar sensor [1] which operates at 60 GHz for detecting micro-motion from human fingers. However, the range of this application needs to be improved since it is challenging to detect micro-motion if the distance between the hand and the radar is larger than 50 cm. Another challenge for human hand recognition based on radar is that the radar will detect both human hand and human body motions if the radar is set up front of the users, and thus is vulnerable to undesired motion noise and interference.

In this paper, a portable, programmable FMCW Radar operating at 77 GHz is used to investigate the feasibility of human hand recognition for remote control of computers or smart TVs. The radar will be set up in front of the user while the user moves at a distance from 20 cm to 150 cm in the radar's field of view. Compared with the conventional Doppler radar for human gesture recognition [2], the FMCW radar offer a lot more information based on range, velocity, and angle estimation for human hand gesture detection [3]. A noise removal method and a range gating method to separate human hand and human body will be introduced.

II. Theory

A. Noise Removal Method

An FMCW radar can track the hand movement and extract the information for range, velocity, and angle estimation [4]. However, while the user is moving hand, the FMCW radar will not only recognize hand movement but also detect a small motion of human body, unwanted movement from other moving targets exist. The radar also detects other objects from surrounding environment. These unwanted detections are considered noise. These noises have significant effect and they cause wrong detection for hand gesture recognition. Fig. 1 shows the multiple objects with power, range, velocity, and angle estimation with noise present.

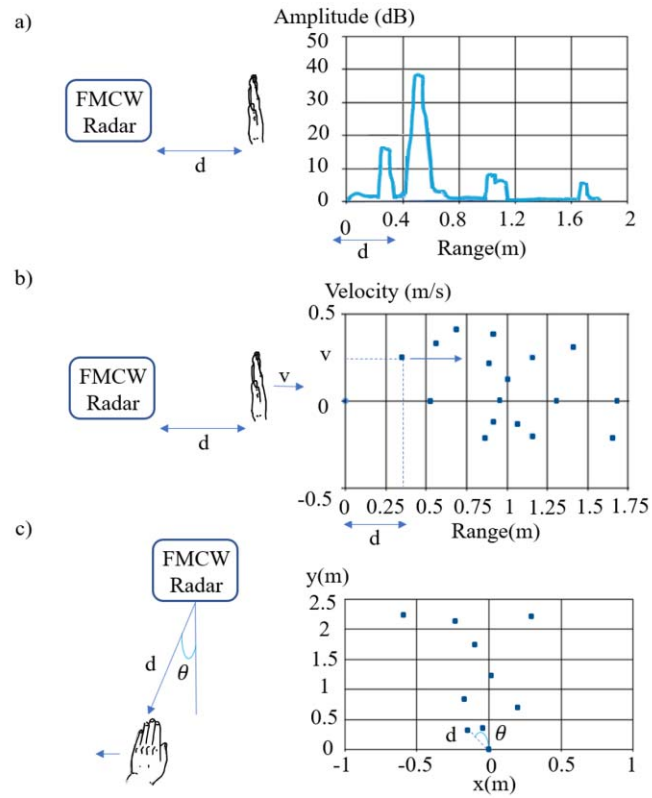

Fig. 1. a) Range estimation. b) Velocity estimation. c) Angle estimation

For hand gesture recognition application for remote control, a noise removal method is introduced. The method is mainly based on the range and power level information (Fig. 1a) extracted from FMCW Radar. Depending on the distance, the detected objects from FMCW Radar will have different power level. When the user moves hand front of the FMCW Radar, there will be the shifted objects for velocity and angle (Fig. 1b and Fig. 1c). The shifted objects for angle and velocity will change significantly. However, the power level will only change slightly since the changing in the range is insignificant. By comparing the range and power level of moving object in

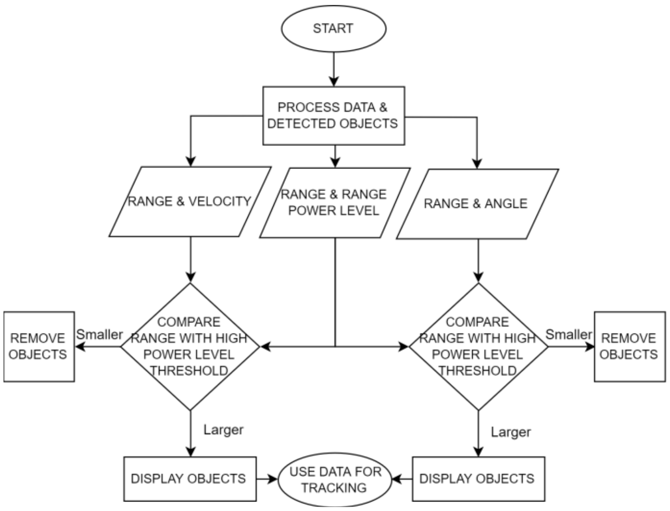

Fig. 2. Noise removal method flow chart.

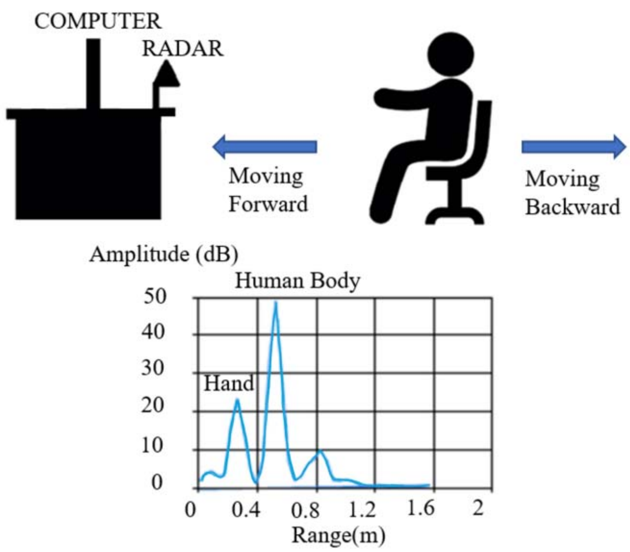

Fig. 3. Detection of human body and human hand by FMCW Radar.

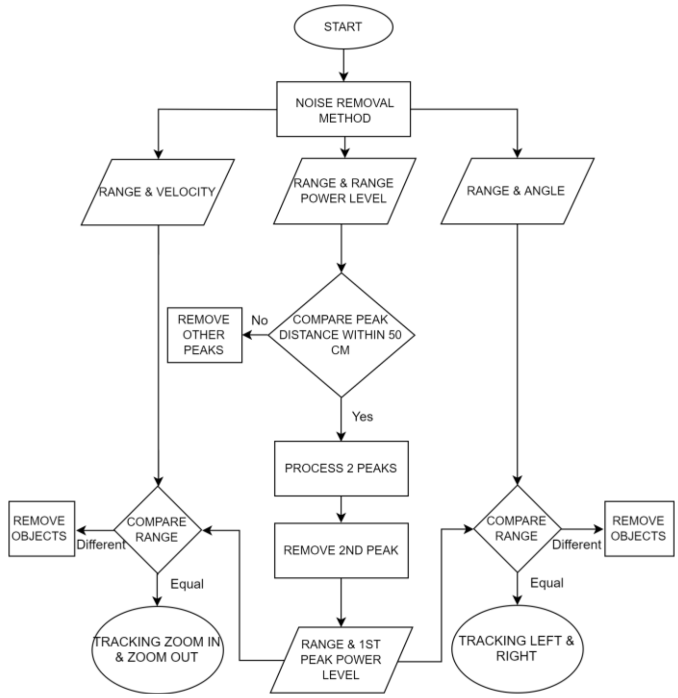

Fig. 4. Range gating method flow chart.

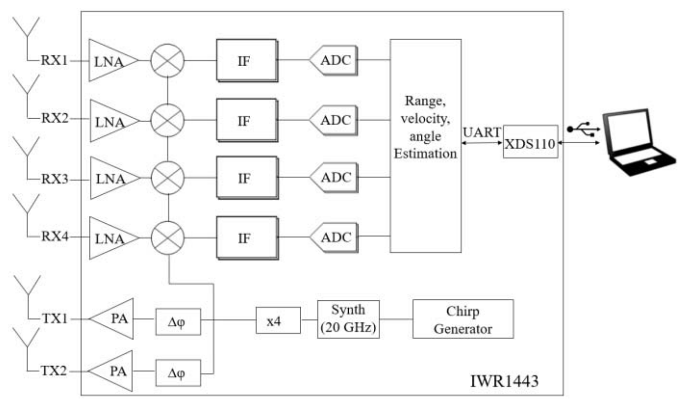

Fig. 5. Block Diagram of the FMCW Radar System.

the velocity and angle graphs with the range graphs. These unwanted moving objects will be eliminated, and the useful information will be applied to range gating method to track human hand. A flow chart of noise removal method is shown in Fig. 2.

B. Range Gating Method.

When set up the radar front of the user, the FMCW radar will not only detect hand movement but also detect human body. The human body will become the obstacle for human hand gesture recognition especially when the user moving in the radar's field of view. Fig. 3 will illustrate this situation.

To separate the peak between human hand and human body, the range gating method will be introduced. The method will create the gate dividing human hand and human body, even when the user is moving. By removing human body peak, the radar only detects human hand movement and applies this movement to remote control application. After performing noise removal method, the range information will be the range and the power of human hand, human body, and other unmoving objects in the radar's field of view. The velocity information will be the hand moving, immobile human body and other objects. The angle information will be the changing angle of human hand, the stable angle of human body, and the unmovable objects. The maximum distance between human hand and human body is about 50 cm. The comparison between these peak within the range 50 cm based on the range and the power level will filter these other unwanted objects. After detecting human hand peak and human body peak in the range estimation, a gate will be created to separate these two peaks, this gate also works while the user is moving. Finally, the range and the power information of the human hand will be separated from human body and other objects in the sur-

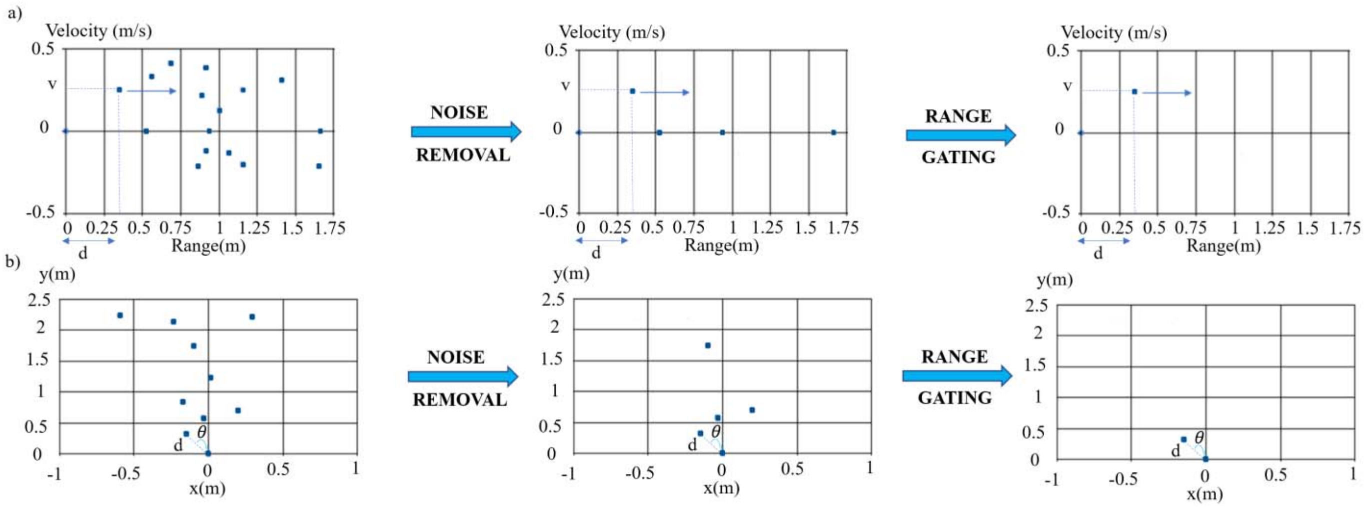

Fig. 6. a) Noise removal and range gating method result for velocity estimation. b) Noise removal and range gating method result for angle estimation.

TABLE I. AVERAGE % OF PRECISELY RECOGNIZED GESTURES OF FMCW RADAR FROM 0.3M TO 1.5M

Distance	Right	Left	Zoom in	Zoom out
0.3 m	97.9	97.5	98.3	98.3
0.7 m	96.6	96.3	97.5	97.5
1 m	91.6	92.9	95.8	96.3
1.2 m	83.3	86.6	89.1	90
1.5 m	4.1	6.25	12.5	10.4

rounding environment, and this information will compare one more time with velocity and angle information extracted after noise removal method. Therefore, all unwanted objects are also removed from the velocity and angle information. The final information from velocity estimation is used for tracking zoom in and zoom out gestures. Similarly, the information from the angle estimation will be used to track left and right movement. The flow chart of the range gating method is shown in Fig. 4.

III. EXPERIMENT AND RESULTS

A. Hardware

The radar system uses IWR1443 Evaluation Module, a programming FMCW Radar, from Texas Instrument (TI). IWR1443 can transmit a programming chirp signal at 77 GHz from 2 TX antenna then receive the reflected signal from 4 RX antenna [5, 6]. The FMCW Radar will perform range, velocity and angle estimation then transmit all analyzed results through universal asynchronous receiver-transmitter (UART) to the computer. Visual Studio with C# programming language is used to write a program which obtains data from the FMCW radar. This information is analyzed and processed by performing noise removal and the range gating method. Afterwards, a command is sent to the computer to control an application. The block diagram of the FMCW Radar system is shown in Fig. 5.

B. Gestures and Use Cases

The 4 sets of gestures will provide for FMCW radar system. The FMCW radar set up front of the user:

Swiping Right (R): Moving one hand from left to right, the program will send one keystroke “RIGHT” to the computer.

Swiping Left (L): Moving one hand from right to left, the program will send one keystroke “LEFT” to the computer.

Zoom In (ZI): Moving one hand forward to the FMCW Radar. The program will send keystroke “CTRL +” continuously to the computer.

Zoom Out (ZO): Moving one hand backward from the FMCW Radar. The program will send keystroke “CTRL -” continuously to the computer.

C. Testing

The FMCW radar system was tested on 3 different computers: 1 desktop PCs, 1 LG Laptop and 1 MacBook Pro 13”. To guarantee that the system works with different hand sizes, we tested the program with 3 individuals. A male with big hand size, a female with small hand size and a male with normal hand size were invited to test the system in a classroom. The FMCW Radar will be set up in front of the users. The users will sit on a chair and they will perform 4 gestures: R (Swiping right), L (Swiping left), ZI (Zoom in), ZO (Zoom out). The initial distance is 0.3m. After performing 4 gestures, they will move away from the FMCW Radar stopping at 0.7 m, 1 m, 1.2 m, and 1.5 m, repeating the 4 gestures at each point. The users were asked to control two applications using these gestures: (i) to control pdf file using the mentioned gestures for “next”, “previous”, “zoom in” and “zoom out” the pdf file. (ii) to watch the next image and previous image in Photo Viewer, then zoom in and zoom out the image. Each user will perform 10 repetitions for each gesture in different distance. 240 repetitions for each gesture were recorded in total. The result of noise removal and range gating method is shown in Fig. 6. Based on these data sets, performance results are shown in Table 1.

IV. CONCLUSION

A 77 GHz programmable FMCW Radar was used for human hand gesture recognition and applied to remote control for a computer. It had been demonstrated that the noise removal method and the range gating method can enable the FMCW Radar to recognize four gesture commands: swiping left, swiping right, zoom in, and zoom out at a distance varying from distance of 0.3 m to 1.2 m. Future work will focus on generating more gesture commands and apply to remote control of more smart devices.

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