Using mmWave radar sensor detects the objects hidden by obstacles

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Introduction

Millimeter wave (mmWave) radar technology is a unique type of radar technology employing short wavelength electromagnetic waves. These radar systems emit electromagnetic wave signals which are then reflected by objects in their path. By capturing and analyzing these reflected signals, radar systems can ascertain the distance, speed, and direction of the objects.[1]

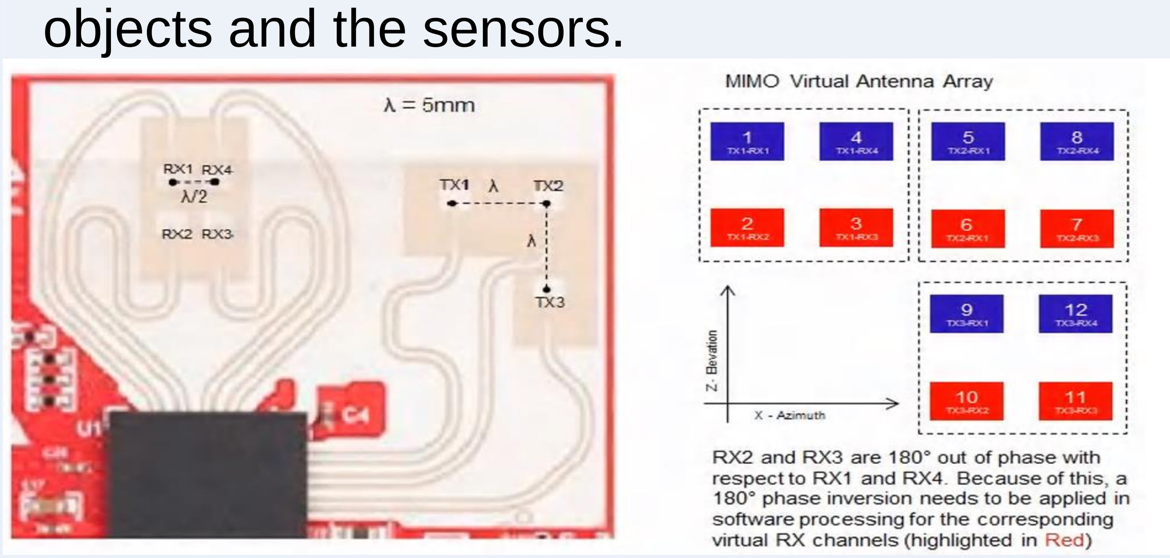
Besides that, mmWave has many merits to implement widely. It has short wavelengths which enables high-resolution imaging and detection. This allows for the detection of smaller objects. And Millimeter waves can penetrate certain materials such as clothing, plastic, and drywall, allowing detection of objects concealed behind these materials.

Objectives

In the research, We need to use the given data to derive the objects density diagram and some corresponding crucial traits like reflection power, reflection directions, and the angles of Arrival and Departure. After getting the values of these, we could easily locate the position and understand something useful.

Methods

Task1: We first construct a rough model, where signals are emitted from the transmitter, reflected by objects, and then received by the receiver. In this process, we write Python code to obtain intensity maps for each transmitter and its corresponding receiver (with different peaks representing different positions). By observing the images, we can determine the distance between the objects and the sensors.



More importantly, we need to calculate the values of AOA and AOD. Assuming the distance between the objective and RX is d, we can determine the phase difference as

$$\Delta\varphi = \frac{2\pi\Delta d}{\lambda}$$

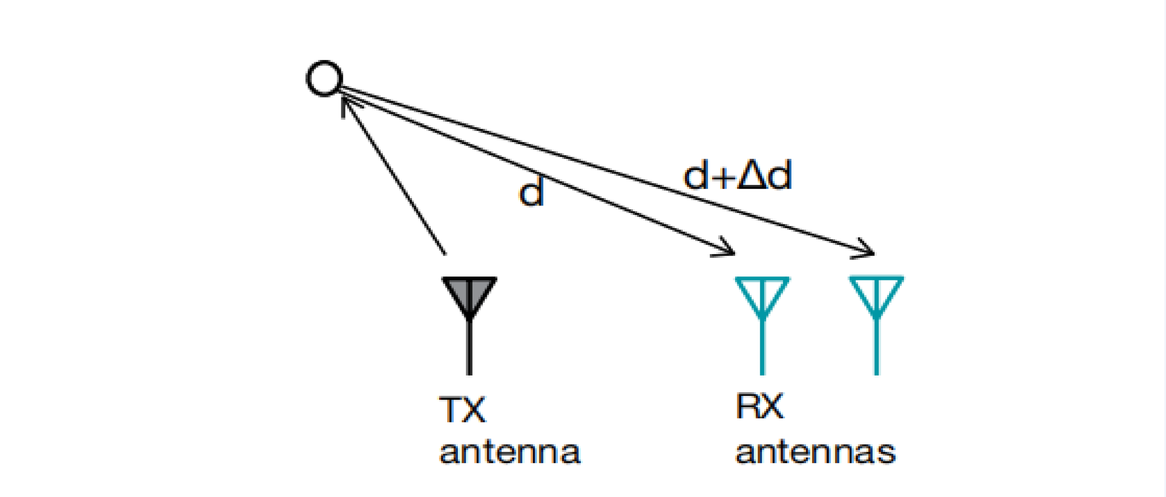
According to formula:

$$\Delta d = l\sin(\theta)$$

Finally

$$\theta = \sin^{-1}\left(\frac{\lambda\Delta\varphi}{2\pi l}\right)$$

Similarly, When calculating the angle of departure we arrange serveral transmitters to correspond one single receiver. We could derive the θ using the same formula.



Based on the location of TX and RX and the AOA and AOD, the intersaction of the two rays is the objective that we want to find.

Task2: Based on previous research we detect some vital signals of people. We need to introduce a brand-new concept called Fast Fourier Transform. FFT can transform time-domain data into frequency-domain data, which is very useful for analyzing the frequency components in periodic signals. Some traits are unique to humans, such as breathing and heart beating.And here are some merits that we use FFT.[2]

(1). FFT can analyze the frequency components of respiratory and heartbeat signals from the spectrum

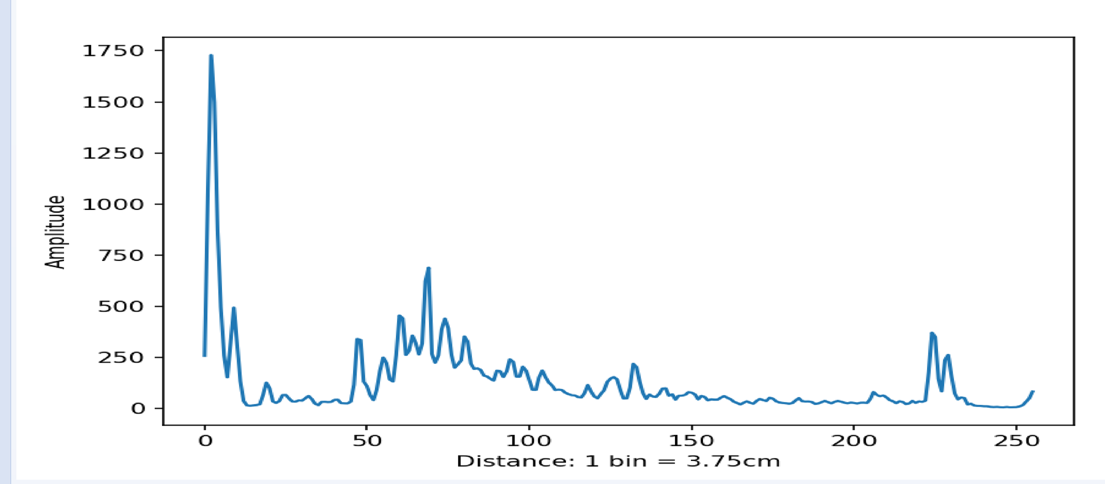
(2). the spectrum after FFT can determine the main frequency components of the signal by finding peaks. By identifying peaks in the spectrum, important physiological parameters such as respiratory rate and heart rate can be estimated.

(3). FFT can assist in analyzing the strength distribution of respiratory and phase signals at different frequencies, thereby revealing the frequency domain characteristics of the signal, such as the presence of periodic changes at specific frequencies.

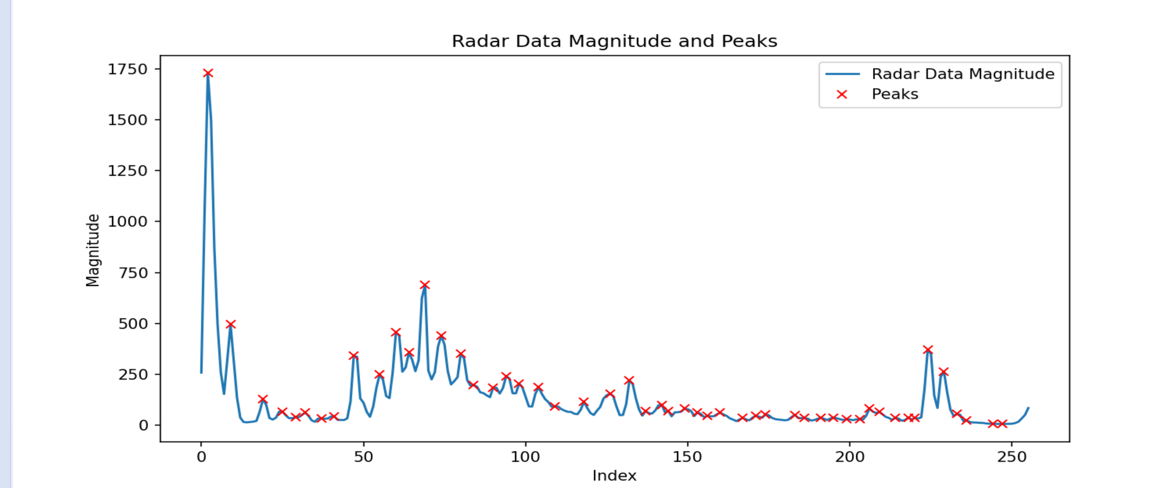
Finally, we select the highest peak from them and the result should be the vital signals like breathing rate and heart beating rhythm.

Results

Task1: Python diagram:(the mean of 12 results)



The reflection points and parts of the magnitudes and its corresponding location.




```
Radar data magnitude information: [ 258.59877412 1049.07944984 1729.01441477 1498.3272046   872.64470502
  496.85461868  260.95769734  153.45431017  320.45466085  494.55797794
  315.90757715  135.30961199   37.68486157   16.36261844   14.16038387
   15.86091228   17.66379822   21.46820055   67.08221576  127.78350291
  100.26795088   35.428185     27.95519093   36.97954053   66.9196589
   67.45587102   49.31534836   35.13621849   34.24380405   40.56718184
   39.18574604   50.59536798   62.32648868   46.97953924   24.54356882

Indices of found peaks: [  2   9  19  25  29  32  37  41  47  55  60  64  69  74  80  84  90  94
  98 104 109 118 126 132 137 142 144 149 153 156 160 167 171 174 183 186
 191 195 199 203 206 209 214 218 220 224 229 233 236 244 247]
```

A demonstration of one point’s AOA and AOD

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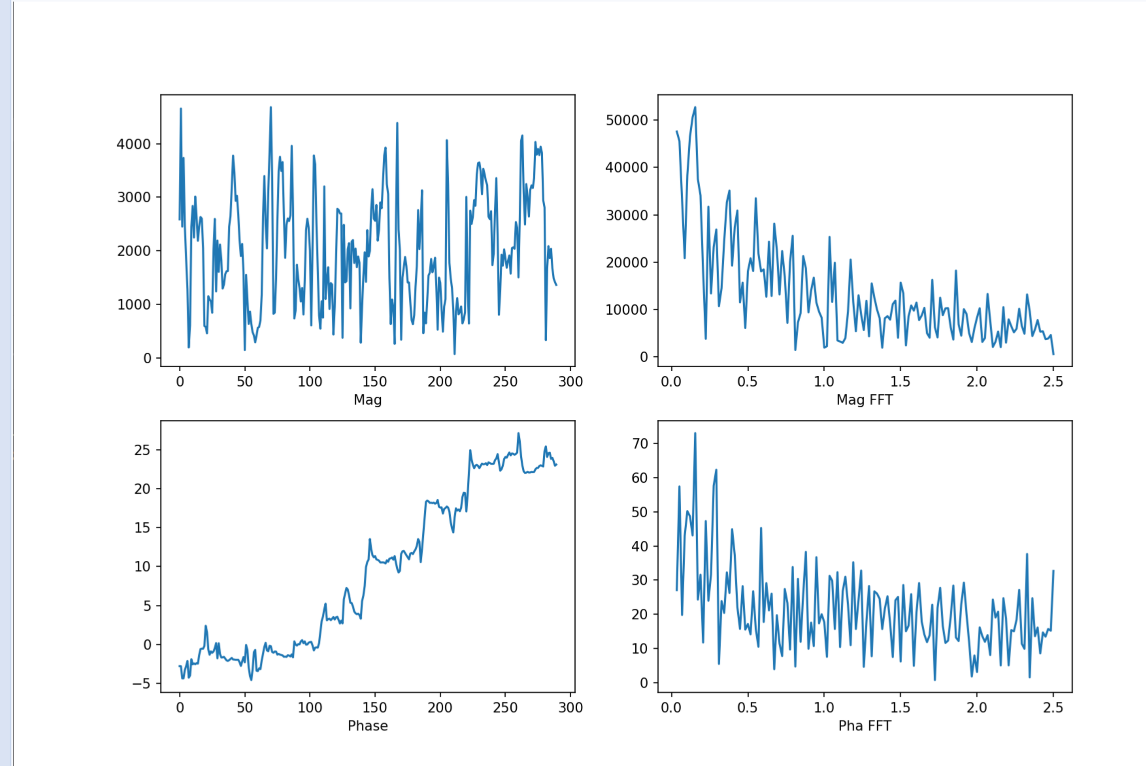
2: (-12.687601365731384, -4.823687097031443)
```

Task2: The largest data and the second largest data

```
52766.14561451913 52766.14561451913
Using Mag:  3165968.736871148 3165968.736871148
12
```

Its result and transformation



Conclusions

From task 1, we have formulated a clear process to get the position of an object using mmWave detection. In the following resaerch, we use FFT to detect the vital traits of a certain object.

References

[1].The fundamentals of millimeter wave radar sensors.https://www.ti.com/lit/wp/spyy005a/spyy005a.pdf

[2].https://en.wikipedia.org/wiki/Fast_Fourier_transform

My python codes have uploaded to GitHub: https://github.com/YunxuanLi0619/gears_ncsu/tree/master